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Service Function Chaining (SFC) Use Cases
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Abstract

The delivery of value-added services relies on the invocation of advanced Service Functions in a sequential order. This mechanism is called Service Function Chaining (SFC). The set of involved Service Functions and their order depends on the service context.

This document presents a set of use cases of Service Function Chaining (SFC).

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1. Introduction

The delivery of Value-Added Services (VAS) relies on the invocation of various Service Functions (SFs). Indeed, the traffic is forwarded through a set of Network Elements embedding Service Functions, e.g.:

a. Direct a portion of the traffic to a Network Element for monitoring and charging purposes.

b. Before sending traffic to DC servers, steer the traffic to cross a load balancer to distribute the traffic load among several links, Network Elements, etc.

c. Mobile network operators split mobile broadband traffic and steer them along an offloading path.

d. Use a firewall to filter the traffic for IDS (Intrusion Detection System)/IPS (Intrusion Protection System).

e. Use a security gateway to encrypt/decrypt the traffic. SSL offloading function can also be enabled.

f. If the traffic has to traverse different networks supporting distinct address families, for example IPv4/IPv6, direct the traffic to a CGN (Carrier Grade NAT, [RFC6888][RFC6674]) or NAT64 [RFC6146].

g. Some internal service platforms rely on implicit service identification. Dedicated Service Functions are enabled to enrich packets (e.g., HTTP header enrichment) with the identity of the subscriber or the UE (User Equipment).

h. Operators offer VAS on a per subscription basis. It is desirable to steer traffic only from the subscribers, who have subscribed to VAS, to the relevant service platforms.

This document describes some use cases of Service Function Chaining (SFC). It is not the purpose of this document to be exhaustive, but instead, we try to draw the set of deployments context that are likely to see SFC solutions deployed.

For most of the use cases presented in this document,

o Instantiated SFC are driven by business and engineering needs.

o The amount of instantiated SFCs can vary in time, service engineering objectives and service engineering choices.

o The amount of instantiated SFCs are policy-driven and are local to each administrative entity.

o The technical characterization of each Service Function is not frozen in time. A Service Function can be upgraded to support new features or disable an existing feature, etc.

o Some stateful SFs (e.g., NAT or firewall) may need to treat both outgoing and incoming packets. The design of SF Maps must take into account such constraints, otherwise, the service may be disturbed. The set of SFs that need to be invoked for both direction is up to the responsibility of each administrative entity operating an SFC-enabled domain.

- For subscription-based traffic steering, subscriber-awareness capability is required. A UE is allocated a dynamic IPv4 address and/or IPv6 prefix when attaching to a network. This IPv4 address and/or IPv6 prefix can change from time to time. The requirement is to be able to correlate an IPv4 address and/or IPv6 prefix to a subscriber identity from that will be used to trigger the invocation of some Service Functions.

- Some Service Functions may be in the same subnet; while others may not. Service Functions are deployed directly on physical hardware, as one or more Virtual Machines, or any combination thereof.

2. Terminology

This document makes use of the terms defined in [I-D.boucadair-sfc-framework].

Service Flow: packets/frames with specific service characteristics (e.g., packets matching a specific tuple of fields in the packet header and/or data) or determined by some service-inferred policies (such as access port and etc.).

Gi interface: 3GPP defines the Gi interface as the reference point between the GGSN (Gateway GPRS Support Node) and an external PDN (Packet Domain Network). This interface reference point is called SGi in 4G networks (i.e., between the PDN Gateway (PGW) and an external PDN)[RFC6459].

3. Service Function Chaining Deployment Scenarios

Service Function Chains can be deployed in a diversity of scenarios such as broadband networks, mobile networks, and DC center. This section describes a set of scenarios for Service Function Chaining deployment.

3.1. Use Case of Service Function Chain in Broadband Network

In broadband networks, an operator may deploy value-added service nodes on POP (Point of Presence) site. These service nodes compose different Service Function Chains to deliver added-value services.

```
                 ------                                            ------
              //         \\   *******************           //         \\
   +-----+    |             | * +---+           * +---+     |             |
   |CPE  |--->+  Metro     +-->+BNG+>+-------+--->|CR +--->+ Internet    |
   +-----+    |             | * +---+ |       ^  * +---+     |             |
              \\         //   *       v       |  *           \\         //
                 ------       *      ++-------++ *              ------
                              *      | Service | *
                              *      | Chain   | *
                              *      +---------+ *
                              *******************
                         Service Function Chain deployment position
```

Figure 1: An example of Service Function Chain in Broadband Networks

Figure 1 illustrates a possible deployment position for Service Function Chaining: between BNG and CR (Core Router). The Service Function Chain shown in Figure 1 may include several Service Functions to perform services such as DPI, NAT44, DS-Lite, NPTv6, Parental control, Firewall, load balancer, Cache, etc.

3.2. Use Case of Service Function Chain in Mobile Networks: The Gi/SGi Interface

3GPP defines the Gi interface as the reference point between the GGSN (Gateway GPRS Support Node) and an external PDN (Packet Domain Network) [RFC6459]. This interface reference point is called SGi in 4G networks (i.e., between the PDN Gateway (PGW) and an external PDN) [RFC6459]. Note, there is no standard specification of such reference points (i.e., Gi and SGi) in terms of functions to be located in that segment.

> Note: The use cases do not include 3GPP release details. For more information on the 3GPP releases detail, the reader may refer to Section 6.2 of [RFC6459].

Traffic is directed to/from Internet traversing one or more Service Functions. Note, these Service Functions are called "enablers" by some operators. One example of enabler function is a HTTP Header Enrichment Function. There are also other VAS function such as Parental Control or network-based Firewall. Subscribers can opt-in and opt-out to these services anytime using a self-served portal or by calling the Operator’s customer service.

In light of current deployments, plenty of Service Functions are enabled in the Gi Interface (e.g., DPI, billing and charging, TCP optimization, web optimization, video optimization, header enrichment, etc.). Some of these Service Functions are co-located on the same device while others are enabled in standalone boxes. In order to fulfill new business needs, especially to offer innovative added-value services, the number of enabled Service Functions in the Gi Interface is still growing. Some of these functions are not needed to be invoked for all services/UEs, e.g.,:

- o TCP optimization function only for TCP flows.
- o HTTP header enrichment only of HTTP traffic.
- o Video optimization function for video flows.
- o IPv6 firewall + NAT64 function for outgoing IPv6 packets.
- o IPv4 firewall + NAT64 function for incoming IPv4 packets.

3GPP has defined Traffic Detection Function (TDF) which implements DPI (detection) functionality along with enforcement and charging of the corresponding detected applications [TS.23203]. TDF resides on Gi/SGi interface. In reference to the examples shown in Figure 2, a TDF function as defined by 3GPP can be used instead of some legacy DPI solutions.

> Note: It was tempting to use TDF and DPI terms interchangeably, but given the diversity of deployments involving DPI modules the text uses DPI to refer to legacy deployments. The behavior of such DPI modules is deployment-specific.

Several (S)Gi Interfaces can be deployed within the same PLMN (Public Land Mobile Network). This depends mainly on the number of PDNs and other factors. Each of these interfaces may involve a differentiated set of Service Functions to be involved.

The current model that consists of adding new "boxes" to fulfill new business guidelines has shown its limit. Concretely, current deployments suffer from the following problems:

- o Complexity (and long time-to-market) to introduce new Service Functions because of the constraint on the underlying topology.

    * The quick time-to-market would allow innovative service launch strategy such as: subscribers are offered a new service feature for a limited period in time for test purposes before massive and industrial deployment of the service feature. The subscription can be managed through a dedicated portal to activate the service feature and trial it. The current

constraint of the underlying topology makes such an approach prohibitively expensive and impractical.

- o Lack of visibility on dependency between Service Functions.

- o Lack of automated and flexible means to assess the impact of withdrawing a Service Function or a feature offered by a Service Function from the traffic forwarding path.

- o The connectivity service logic may be stalled because of the dependency on the physical topology.

- o Sending all traffic through all Service Functions placed in series degrade the user experience, i.e., increased latency and unavailability risk for those subscribers who do not require all or some of the Service Functions to be invoked.

- o Sending all traffic through all Service Functions placed in series increases the capacity required in each Service Function unnecessarily. This would impact the CAPEX (Capital Expenditure).

- o Lack of deterministic means to:

  * Improve service provisioning and delivery.

  * Ease the manageability of the SGi/Gi Interface.

Figure 2 illustrates a use case of Gi/SGi Interface scenario. Figure 2 involves many Service Functions that are enabled in the Gi/SGi Interface: WAP GW, TCP Optimizer, Video Optimizer, Content Caching, FW, NAT (44, 64), etc. This list is not exhaustive but it is provided for illustration purposes.

```
               ***********************************
               *       1     +------+           *
               *  +--------->+WAP GW+----------+ *        ------
               *  |          +------+          | *     //        \\
   +-----+   +---+| +---------+  +-----+       v *    |            |
   |GGSN/+-->|DPI|+>+Optimizer+->|Cache+       +----->+  Internet  |
   |PGW  |   +---+| +---------+  +--+--+       ^ *    |            |
   +-----+     *  |                 |2         | *     \\        //
               *  |                 v          | *        ------
               *  |     3      +-----+  +----+ | *
               *  +----------->+ FW  +->|NAT +-+ *
               *             +-----+  +----+   *
               ***********************************
```

Figure 2: An example of Service Function Chain scenario in the Gi Interface

For example, the traffic from GGSN/PGW to Internet can be categorized and directed into the following Service Function Chains by DPI:

o Chain 1: WAP GW. DPI performs traffic classification function, recognizes WAP protocol traffic, and directs these traffic to the WAP GW through Service Function Chain 1.

o Chain 2: Optimizer + cache + Firewall + NAT. DPI recognizes and directs the HTTP traffic to the Optimizer, Cache, Firewall and NAT in order, to perform HTTP video optimization, HTTP content cache, firewall and NAT function, respectively.

o Chain 3: Firewall +NAT. For other traffic to the Internet, DPI directs these traffic by Service Function Chain 3, the traffic would travel the firewall and NAT in order.

It is worth mentioning that customers (via their UEs) access to some services through the configuration of various APNs on terminals and GGSN/PGW. In current deployments, a GGSN/PGW may be configured with up to hundreds of different APNs. These various APNs can be considered as a classification parameter; as such a GGSN/PGW can forward the traffic relying the APN name information.

SFC allows for example some specific treatment for a given APN traffic, but still current APN-based forwarding is not challenged by SFC.

SFC does not require new features in terminals or in GGSNs/PGWs besides those already proposed (except if a SF Classifier function is instantiated in the GGSN/PGW).

Other deployment use cases other than the one illustrated in Figure 2 can be considered in mobile networks. As shown in Figure 2, the DPI Service Function is set up once just after GGSN/PGW, but it can also be enabled in GGSN/PGW (PCEF function) or it can be enabled in various devices on the Gi/SGi Interface.

Access to internal services is subject to dedicated policies. For example, a dedicated function to update HTTP flow with a UE identifier may be needed to avoid explicit identification when accessing some service platforms operated by the mobile operator.

```
                                              ------
                                           //        \\
+-----+    +----------------------+      |  Internal  |
|GGSN/+--->|HTTP Header Enrichment|----->+  Service   |
|PGW  |    +----------------------+      |  Network   |
+-----+                                    \\        //
                                             ------
```

Figure 3: HTTP Header Enrichment

Figure 3 illustrates a use case of HHE (HTTP Header Enrichment). The HHE SF is able to inject the UE identifier to Internal Service Network for identification purpose.

Note, some mobile networks rely on regional-based service platforms (including interconnection links); while some of Service Functions are serviced in a centralized fashion.

```
+-----+  +---+|  +---------+
|GGSN+->|DPI|+->+Optimizer+-+
|/PGW|  +---+|  +---------+ |      ------                          ------
+-----+                     |   //        \\                     //        \\
+-----+  +---+|  +---------+ |  |            |  +------+  +---+  |            |
|GGSN+->|DPI|+->+Optimizer+-+->+  Regional  |->+ FW  +->+NAT+->+  Internet  |
|/PGW|  +---+|  +---------+ |  |  Network   |  +------+  +---+  |            |
+-----+                     |   \\        //                     \\        //
                            |      ------                          ------
        ...       ...      -+
```

Figure 4: Cross-region services

Figure 4 illustrates a use case of cross-region services, in which the functions that consist of the SFC are located at different regions and flows cross a regional network to go through the Service Function Chains.

3.3. Use Case for Distributed Service Function Chain

Besides the deployment use cases listed above, a Service Function Chain is not necessarily implemented in a single location but can also be distributed crossing several portions of the network (e.g., data centers) or even using a Service Function that is located at an network element close to the customer (e.g. certain security functions).

Multiple SFC-enabled domains can be enabled in the same administrative domain.

For steering traffic to subscription-based Service Functions, the SFC Classifier needs to understand which subscriber a flow belong to in order to retrieve the service profile to apply to this flow. In some contexts, it is not possible to identify in a permanent manner the subscriber by the source IP address because that IP address may be assigned dynamically. Out-of-band methods to correlate the source IP address and a subscriber identifier may be needed in a given administrative domain. The SFC Classifier can rely on pull or push methods to correlate an IP address and/or IPv6 prefix to a subscriber identity. Examples are querying the PCRF or receiving RADIUS Accounting messages respectively.

For steering traffic to traffic management Service Functions such as video optimisation platform, in mobile network, it is desirable to perform optimisation on when required. That is when there is congestion in the Radio cells. One option for the SFC Classifier to have this congestion-awareness is for the network to provide this information to the SFC Classifier, directly, or via an intermediate actionable-intelligence function, which can combine other inputs or policies. How those policies and feedback data are configured to the SFC Classifier may be specific to each administrative domain.

3.4. Use Case of Service Function Chain in Data Center

In DC (Data Center), like in broadband and mobile networks, Service Function Chains may also be deployed to provide added-value services.

Figure 5 illustrates a possible scenario for Service Function Chain in Data Center: SFs are located between the DC Router (access router) and the Servers. From Servers to Internet, there are multiple Service Functions such as IDS/IPS, FW, NAT lined up and a monolithic SFC created for all incoming traffic.

```
   ***********************************************
   * +------+                                    *
   * |Server+-+                                  *
   * +------+ |                                  *            ------
   *          |                                  *         //        \\
   * +------+ |  +-------+   +--+   +---+   +---------+   |            |
   * |Server+-+->|IDS/IPS+-->|FW+-->|NAT+-->|DC Router|-->+  Internet  |
   * +------+ |  +-------+   +--+   +---+   +---------+   |            |
   *          |                                  *         \\        //
   *          |                                  *            ------
   *   ...   -+                                  *
   *                                             *
   *   ...                                       *
   *                                             *
   *                      DC                     *
   ***********************************************
```

Figure 5: Service Function Chain in Data Center

3.5. Use Case of Service Function Chain in Cloud CPE

Cloud CPE is one deployment scenario where the value-added service functions are centralized (e.g., hosted in the network or cloud side), leaving the subscriber side box with basic L2/L3 functionalities. In this scenario, all the value added services are configured by subscribers and enabled in the network side.

Subscribers can define their own added value services. The Cloud CPE will translate those services requests into chains of Service Functions. Such architecture must support means to differentiate subscribers and their traffic.

```
   +------+                    +------Cloud CPE-----+
   |L2-CPE|--+                 |          +---+     |
   +------+  |                 |   +--+  /|ACL|--   |     +------------+
      ...    |==Encapsulation==|---|FW|-- +---+  \__|_____|  Internet  |
   +------+  |                 |   +--+ \        /  |     +------------+
   |L2-CPE|--+                 |         +-----+    |
   +------+                    |         |TCP-O|    |
                               |         +-----+    |
                               +--------------------+
```

Figure 6: SFC in Cloud CPE

4. Abstraction of SFC in Different Deployment Scenarios

This section presents the SFC scenarios from a different angle, i.e., the abstraction of SFC use cases in different deployment scenarios. Each of the use case may belong to one or many of the categories listed below:

Category	Description
Per-service Characteristic SFC	Chain different Service Functions based on service/application characteristics
Per-user/subscription SFC	Chain different Service Functions based on user requirements or subscription information. Note, this does not mean that millions of SFCs will be instantiated but SF classification is subscriber-aware.
TE-Oriented SF	Chain different Service Functions for Traffic Engineering purposes. This may includes load, utilisation, planned maintenance, etc.
Bi-directional Flow SFC	Function path that contain bi-directional Service Functions
SFC over Multi-Underlay Networks	Service Functions distributed over different underlay networks
SFC over Service Functions Forking	SFC that contains the paths for different service or applications

4.1. Per-service characteristic SFC

The traffic in a network is usually forwarded based on destination IP or MAC addresses. In an operator's network, some Service Functions are implemented, where traffic is steered through these Service Functions in a certain sequence according to service characteristics and objectives.

```
                                     +---------------------------+
                           +-------->|Service Function Chaining A
            +------------+     |         +---------------------------+
    ------->|Service     |--->|
            |Classifier  |     |         +---------------------------+
            +------------+     +-------->|Service Function Chaining B|
                                     +---------------------------+
```

Figure 7: General Service Function Chain

Traffic enters a SFC-enabled domain in a service classifier, which identifies traffic and classifies it into service flows. Service flows are forwarded on a per SF Map basis.

4.2. Per-user/subscription requirement SFC

In operator networks with user subscription information, it is considered as a value added service to provide different subscribers with differentiated services. Subscribers may subscribe different services and the order handling at the operator side will translate those subscription request into configuration operations so that the service will be appropriately delivered to the subscribers. Configuration operations include in particular the provisioning of classification rules.

4.3. TE-Oriented SFC

TE-oriented SFC is required by operators in achieving flexible service operating. For example, if certain paths are congested or certain Service Functions are overloaded, SFC forwarding should be inferred accordingly.

4.4. SFC for Bi-directional Flow

Some Service Functions, for example, NAT or TCP optimization, need to handle bi-directional flows, while others SFs such as video optimization don't need to handle bi-directional flows.

Due to IPv4 address exhaustion, more and more operators have deployed or are about to deploy IPv6 transition technologies such as NAT64 [RFC6146]. The traffic traversing a NAT64 function may go through different types of IP address domains. One key feature of this scenario is that characteristics of packets before and after processed by the service processing function are different, e.g., from IPv6 to IPv4. The unpredictability of processed packets, due to the algorithm in the Service Function, brings difficulties in steering the traffic.

A variety of hosts can be connected to the same network: IPv4-only, dual-stack, and IPv6-only. A differentiated forwarding path can be envisaged for each of these hosts. In particular, DS hosts should not be provided with a DNS64, and as such there traffic should not be delivered to a NAT64 device. Means to guide such differentiated path can be implemented at the host side; but may also be enabled in the network side as well.

```
     +---------+                           +----------+
====>+ SF C    +        +----------+       |   SF E   |===>+---+
|    +---------+=======>|   SF     |=======>+----------+    |INT|
+<======================|   NAT    |<======================|NET|
                        +----------+                        +---+
```

Figure 8: Service Function Chain with NAT64 function

Figure 8 shows a specific example of Service Function Chain with NAT function. Service flow1 is processed by SF(Service Function) C, NAT and E sequentially. In this example, the SF NAT performs NAT64. As a result, packets after processing by the SF NAT are in IPv4, which is a different version of IP header from the packets before processing. Service Function Chaining in this scenario should be able to identify the flow even if it is changed after processed by Service Functions.

4.5. SFC over Multiple Underlay Networks

Operators may need to deploy their networks with various types of underlay technologies. Therefore, Service Function Chaining needs to support different types of underlay networks.

```
   +---------+         +----------+       +----------+
-->+ SF A    |         | SF B     |       | SF C     +-->
   +----+----+         +---+-+----+       +-----+----+
        |                  ^ |                  ^
        |     ------       | |     ------       |
        |   //      \\     | |   //      \\     |
        |  |  Ethernet  |  | v  |           |  |
        +->+  network   +->+ +->+ IP network +->+
           |            |       |           |
           \\        //         \\        //
              ------               ------
```

Figure 9: multiple underlay networks: Ethernet and IP

Figure 9 illustrates an example of Ethernet and IP network, very common and easy for deployment based on existing network status, as underlay networks. SF(Service Functions) A, B and C locate in

Ethernet and IP networks respectively. To build a Service Function Chain of SF A, B and C, Service Function Chaining needs to support steering traffic across Ethernet and IP underlay networks.

4.6. SFC over Service Path Forking

To enable service or content awareness, operators need DPI functions to look into packets. When a DPI function is part of a Service Function Chain, packets processed by the DPI function may be directed to different paths according to result of DPI processing. That means a forking service path.

In this use case, the switching SF is another classifier which need to classify flow and shepherd them to different paths.

```
     +---------+        +----------+        +----------+
     |         |        |          |        |          |
---->| Firewall+------->+  DPI     +------->+anti-virus|--->
     |         |        |          |        |          |
     +---------+        +-----+----+        +----------+
                              |
                              V
                        +-----+----+
                        |          |
                        | Parental |
                        | control  |
                        +-----+----+
                              |
                              V
```

Figure 10: a forking service path

Figure 10 shows the use case of a forking service path. Traffic first goes through a firewall and then arrives at DPI function which discerns virus risk. If a certain pre-configured pattern is matched, the traffic is directed to an anti-virus function.

Such DPI function may fork out more than one path.

Service function sharing is sub-category of the service function forking. Some carrier grade hardware box or Service Functions running on high performance servers can be shared to support multiple Service Function Chains. Following is an example.

```
       SFC1    +---------+        +--------+
       ------->+---------+------->+--------+--->
       SFC2    |Firewall |        |Video   |
       ------->+-->+     |        |Opt     |
               +---|-----+        +--------+
                   |
                   v
               +---+-----+
               |   |     |
               |Parental |
               |Control  |
               +---+-----+
                   |
                   v
```

Figure 11: Two Service Function Chains share one Service Function

In Figure 11, there are three Service Functions, firewall, VideoOpt and Parental Control, and two Service Functions Chains SFC1 and SFC2. SFC1 serves broadband user group1 which subscribes to secure web surfing and Internet video optimization, while SFC2 serves broadband user group2 which subscribes to secure web surfing with parental control. SF Firewall is shared by both Service Function Chains.

5. Security Considerations

This document does not define an architecture nor a protocol. It focuses on listing use cases and typical Service Function examples. Some of these functions are security-related.

SFC-related security considerations are discussed in [I-D.boucadair-sfc-framework].

6. Acknowledgements

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