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Applicability & Manageability of SCONE signal for a mobile network
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Abstract

This document addresses the applicability and mangeability of the SCONE signal in mobile networks and the operational considerations for managing it in operator deployments including an ability to provide throughput advice to the application endpoints.

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1. Introduction

SCONE protocol is a signaling mechanism operating at the network/user-plane boundary where it is intended to allow for the network to communicate to application endpoints, a maximum allowable bit-rate for a given UDP 4-tuple. The SCONE signal is meant to carry throughput advice for adaptive bit-rate applications. Purpose of this document is to address applicability and manageability of the SCONE protocol in both the operator networks and application endpoints. The primary focus of this document is on mobile networks, where user-plane functions such as the UPF (5G network) or Packet Data Network Gateway or (PGW) for a (4G network) that are capable of generating throughput advice to guide adaptive bit-rate applications. However, the same concepts may also apply to other access networks where similar advisory mechanisms are useful.

This document is not a protocol specifications and its purpose is to focus on SCONE protcol’s applicability and manageability in the operator network.

2. Conventions and Definitions

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in BCP 14 [RFC2119] [RFC8174] when, and only when, they appear in all capitals, as shown here.

3. Applicability of SCONE Signal in Mobile Networks

Mobile and access networks frequently encounter variable conditions due to congestion, radio interference, or dynamic resource allocation. Even applications that use adaptive bit-rate may experience degraded performance or inefficiencies under such conditions. The SCONE protocol enables network elements to provide throughput advice directly to applications, allowing them to adjust sending rates proactively, improving end-user Quality of Experience (QoE) while helping operators manage network resources efficiently. This document proposes leveraging 3GPP user-plane network elements, including the UPF in 5G and the P-GW in 4G, to deliver throughput advice over the existing data path in accordance with 3GPP standards.

3.1. Scope of Deployment

The SCONE protocol is intended for deployment within operator-controlled networks, such as 3GPP mobile systems, fixed broadband access networks, or enterprise-managed domains. In these environments, network functions (e.g., UPF, P-GW, or equivalent user-plane entities) are capable of originating throughput advisory messages in response to locally observed policy and network conditions.

SCONE is not designed for open, unmanaged Internet environments where no single administrative entity has end-to-end control.

3.2. Implementing SCONE in Mobile Networks

In 5G, the UPF, and in 4G, the P-GW, are on-path network elements with access to subscriber policy and user-plane connectivity between the UE and the Internet. These elements are capable of generating SCONE throughput advice per application flow, enabling endpoints to adjust sending rates proactively in response to network conditions. SCONE signaling occurs over the existing data path in accordance with 3GPP standards.

The following diagrams illustrate how throughput advice is conveyed within the 5G and 4G packet core, highlighting the role of user-plane network elements in signaling throughghput advice to applications.

```
                             +---------+
                             |   PCF   |
                             +---------+
                                  | Subscriber
                                  V Policy Rules
                             +---------+
                             |   SMF   |
                             +----+----+
                                  | Flow
                                  v Policy Rules
   +--------+               + +---------+-+
   | Client |/--------------\ |  SCONE  | |      __
   |   App  |\--------------/ | Advisor | |    __(  )__
   +--------+     SCONE      | +---------+ |   (        )   +----------+
   |   OS   |  (advised bit |             +--( Internet )--+ Content  |
   +--------+   rate and    |      UPF    |   (         )  | Provider |
   |  Modem |   other IEs)  |             |    (__)(___)   +----------+
   +----+---+               +------+------+
        |                          |
        |         +-----+          |
        +---------+ gNB +----------+
                  +-----+
```

Figure 1: SCONE Integration within the 5G SA Network

Similarly, the SCONE signal for 4G network is shown below.

```
                             +---------+
                             |  PCRF   |
                             +----+----+
                                  | Flow
                                  v Policy Rules
   +--------+               + +---------+-+
   | Client |/--------------\ |  SCONE  | |      __
   |   App  |\--------------/ | Advisor | |    __(  )__
   +--------+     SCONE      | +---------+ |   (        )   +----------+
   |   OS   |  (advised bit |             +--( Internet )--+ Content  |
   +--------+   rate and    |     P-GW    |   (         )  | Provider |
   |  Modem |   other IEs)  |             |    (__)(___)   +----------+
   +----+---+               +------+------+
        |                          |
        |         +-----+       +--+---+
        +---------+ eNB +-------+ S-GW |
                  +-----+       +------+
```

Figure 2: SCONE Integration within the 4G Network

4. SCONE Manageability & Operational Considerations

The SCONE protocol is designed to operate independently of transport-layer congestion control algorithms. It provides a signaling path at the network/user-plane boundary, rather than per-flow congestion feedback, and is explicitly designed to work in 3GPP or other operator-controlled domains where the UPF or another network function can generate throughput advice.

This section describes how the SCONE protocol can be deployed and managed within 3GPP networks, including support for SCONE packets over established PDU sessions.

4.1. 3GPP Defined PDU Session Establishment Procedures

The following high-level functions, defined within 3GPP specifications, are relevant to SCONE manageability, as SCONE packets traverse established PDU sessions:

1. Packet Data Network (PDN) Connection / PDU Session (5G) A logical connection between the UE and the P-GW (in 4G) or UPF (in 5G), allowing the UE to exchange IP packets with external networks. Each PDN Connection/PDU Session is associated with an APN (4G) or DNN (5G).

2. IP address Allocation

   During PDN Connection/PDU Session establishment, the UE is allocated an IP address (IPv4, IPv6, or both) used for communication with external networks.

3. Bearer Establishment Data traffic flows over bearers, each defining QoS characteristics for a specific flow. In 4G, a default bearer is created for Internet access, while dedicated bearers may be set up for specialized services. In 5G, the equivalent construct is the QoS Flow.

4. Mobility Management The network ensures seamless UE mobility across cells and base stations while maintaining the ongoing session.

4.2. PDU Session Awareness

SCONE signaling operates only over established PDU sessions. This enables network elements to unambiguously associate throughput advice with specific UEs and application flows. Each session is bound to a DNN (5G) or APN (4G) and to an allocated IP address, ensuring SCONE packets are routed precisely without affecting unrelated traffic.

4.3. Per-Flow Signaling

Throughput advice is applied on a per-4-tuple basis. Network elements MUST maintain flow-specific context to ensure signaling correctness. This enables applications to receive targeted throughput advice while preventing unintended impact on unrelated flows.

4.4. QoS and Bearer Considerations

In 5G, QoS is enforced at the granularity of QoS Flows, identified by a QoS Flow Identifier (QFI). A single PDU session can contain multiple QoS Flows. Operators MAY configure a distinct QFI for SCONE packets to ensure predictable handling, or allow SCONE packets to traverse the same bearer as user-plane traffic when no differentiated treatment is required.

The PCF and SMF MUST be capable of assigning appropriate QoS attributes to SCONE flows to ensure that congestion-control signaling is not degraded under high-load conditions.

4.5. Mobility Handling

During mobility events (e.g., handover or UPF relocation), SCONE state MUST persist across control-plane and user-plane transitions. The SMF and UPF MUST ensure consistent delivery of SCONE packets following mobility procedures.

Where advisory logic is stateful at the UPF, operators SHOULD provide a synchronization mechanism to prevent discontinuities during mobility.

4.6. SCONE Hint to the Network

SCONE-aware applications MUST provide hints to the network element, enabling it to generate appropriate throughput advice for a given 4-tuple. Such hints prevent unnecessary default rate-limiting and allow the network to generate the maximum allowable bit rate. Hints also reduce CPU overhead by eliminating flow classification for SCONE awareness.

4.7. Retransmission of Advised Bit-Rate

Packet loss or non-delivery of SCONE advice reduces effectiveness. Both network elements and applications SHOULD support retransmission or periodic re-sending of SCONE packets to ensure reliable delivery. Conformance depends on both network and endpoint behavior.

4.8. Dynamic Updates

Mobile networks may enforce dynamic rate limits during a sessions due to:

* Changes in RAT Type (requiring updated throughput advice).

* Changes in subscriber policy (exceeding usage thresholds).

* Frequency of updates to maximum allow throughput

* Periodic refreshes of maximim allowable throughput (Define timers for optimal and/or maximum update periodicity).

4.9. Frequency of Updates

The rate at which SCONE updates are issued depends on flow characteristics and available computational resources. Excessively frequent updates may increase CPU load, while infrequent updates may reduce advisory effectiveness. Operators SHOULD define acceptable update periodicity based on application requirements, network capacity, and operational constraints.

4.10. Conformance Monitoring

Network elements providing SCONE throughput advice MUST implement mechanisms to measure compliance, either per application flow or in aggregate. This allows operators to validate advisory effectiveness and adjust policies. SCONE protocol defines a minimum monitoring period for the conformance monitoring.

4.11. Standards Compliance

All SCONE signaling occurs over the existing data path in accordance with 3GPP specifications, ensuring compatibility with established mobile-core procedures and avoiding protocol modifications. SCONE operates without interfering with QoS enforcement or subscriber policies.

4.12. Operations Monitoring and Logging

Operators MAY integrate SCONE signaling into existing OSS/NMS frameworks to enable monitoring, troubleshooting, and fault isolation. Metrics of interest include:

* Rate of SCONE advisory messages issued per session

* Correlation between SCONE advisories and user-plane throughput changes

* Error conditions where SCONE signaling fails to reach the UE

Integration with analytics frameworks (e.g., NWDAF in 5G) MAY be used to assess effectiveness.

4.13. Interworking with Other Congestion Management Mechanisms

SCONE operates independently of transport-layer mechanisms such as ECN or L4S. Operators MAY harmonize multiple congestion signaling methods by policy, or scope deployments to avoid conflicting feedback.

4.14. Other Miscellaneous topics

* SCONE signaling MUST NOT require changes to how a CSP determines video policy for a flow.

* The SCONE signal MUST be extensible beyond 4G/5G.

* Receiver adaptation behavior requires further specification.

* In multi-UPF deployments, only the UPF associated with a given PDU session will send throughput advice. Other UPFs may serve specialized roles but MUST NOT duplicate advisory functions.

By addressing these above operational considerations, SCONE can be managed effectively in mobile networks to enable adaptive bit-rate applications optimize their performance while allowing network operators to utilize network resources efficiently.

5. Detailed view of the User Plane Network Element in Mobile Packet Core

This section describes 5G mobile packet core to explain the role of user-plane network element in mobile packet core and reasons why the 5G User Plane Function (UPF) and 4G P-GW as network elements can be considered candidates for signaling the "throughput advice" to client-application-endpoint. However, the applicability extends to network architectures beyond 4G/5G networks.

The user plane network element in the 5G packet core, termed as the UPF, as shown in Figure 1.

```
               +-----+  Nudm/Nudr  +---------+
               | PCF +-------------+ UDM/UDR |
               +--+--+             +----+----+
                   |                    |
              Npcf |      +-----+       |Nudm
                   +------+ SMF +-------+
                          +--+--+      ___  __
                             | N4     (   )(  )
   +-----+  +---------+   +--+--+    (         )    +------------------+
   | UE |---| gNodeB |----| UPF |----( Internet )---| Content Provider |
   +-----+  +---------+ N3 +- -+-+ N6  (         )    +------------------+
                              | N9     (__(___)
                            +-+---+
                            | UPF |
                            +-----+
```

Figure 3: 5G Mobile Network Architecture

In the 4G packet core, the P-GW (as shown in Figure 2) performs the same role as the UPF does in the 5G mobile packet core.

```
                    +-----+
                    | HSS |
                    +-----+
                       |
                    +-----+          +------+
                    | MME |          | PCRF |
                   /+-----+\         +------+
                  /         \           |
                 /           \          |         ___  __
                /             \         |        /   )(  \
   +-----+  +-----+        +-------+  +-------+    (          )    +----------+
   | UE |---| eNB |--------| S-GW |--| P-GW |----( Internet )---| Content  |
   +-----+  +-----+   S1u  +-------+  +-------+ SGi (         _)   | Provider |
                                                    (__(___)    +----------+
```

Figure 4: 4G Mobile Network Architecture

5.1. 5G Mobile Network Architecture

The UPF is a fundamental component of the 3GPP’s 5G packet core network architecture. UPF is on the data path between the end-user and the Internet, has access to subscriber policy via standard 3GPP N4 interface and is responsible for routing and forwarding user data packets. UPF is the anchor point between the mobile infrastructure and the Packet Data Network. The UPF is responsible for functions such as:

* Packet routing, forwarding, and interconnection to the Data Network (Internet)

* Allocation of User Equipment (UE) IP Address/prefix, in conjunction with Session Management Function (SMF)

* Quality of Service policy enforcement

* Handling of traffic filtering, steering and application detection

* Traffic usage reporting

Note: This is not an exhaustive list of UPF functions. For details refer to [_5G-Arch].

To accomplish above mentioned functions, the UPF has four distinct reference points (interfaces) as defined by the 3GPP and as shown in the figure 1 above:

1. The N3 interface is between the UPF and the 5G Base station.

2. The N4 interface is a connection between the UPF and the Session Management Function (SMF).

3. The N6 interface is between the UPF and the public data network or the Internet.

4. The N9 interface is between instances of UPFs.

5.2. N3 Interface

The N3 interfaces transfers user plane traffic, that is, user data packets between the gNodeB and the UPF. It uses GPRS Tunneling Protocol - User Plane or GTP-U. It replaces the S1-U interfaces from the 4G mobile packet core.

5.3. N4 Interface

The N4 interface connects the UPF and the 5G Session Management Function (SMF). Through N4, the SMF informs the UPF about the subscriber policy and data plans. Additionally, this interface is used to manage session setup, modification, deletion, and for configuring QoS and forwarding rules for user data. The QoS rules contain parameters such as MBR. The N4 interface among others uses Packet Forwarding Control Protocol (PFCP).

Note: SMF also interacts with Policy Control Function (PCF) for functions such as QoS and Charging policy rules, Unified Data Management (UDM) and Unified Data Repository (UDR) for functions such as subscription data and policy plans.

5.4. N6 Interface

The N6 interface connects the UPF to external Data Networks, similar to the SGi interface between the P-GW and the external Data Network for access to services and applications. The interface supports various transport protocols over IP.

5.5. N9 Interface

This interface interconnects two or more UPFs when used in a data path. The interface uses GTP-U protocol for user traffic tunneling including roaming.

Note: In the scenario of 2 or more UPFs in the data path, only one UPF that has access to subscriber policy would send "throughput advice" to the client-application-endpoint.

5.6. User Plane Interface Between UPF and UE

This section describes the N3 interface (between the UPF and gNodeB or gNB) and the air interface between the gNB and UE. For purposes of nomenclature, a Protocol Data Unit (PDU) session is a logical path between a UE and UPF to carry packets belonging to one or more IP flows between UE and DN. A PDU session within a 5G mobile network consists of an air-interface between UE and gNB and GTP-U tunnel between gNB and UPF (N3 interface). Application traffic flows with different QoS requirements get mapped to different QoS treatments based on packet filters and QoS rules configured on the UPF and UE. Below is an example of data flow to/from a UE to the UPF.

1. Uplink Data Flow

   * Apps that are hosted on UE that generate application packets for communication (e.g. web browsing, video streaming).

   * These packets are transmitted to the gNB over the air interface and get mapped to different QoS treatments based on packet filters and QoS rules provided to the UE

   * N3 Encapsulation and Forwarding

     1. The gNB then encapsulates this user-plane data using GTP-U.

   2. It then forwards the encapsulated packets over the N3 interface to the UPF in the 5G mobile packet core.

* UPF Routes Data to External Networks.

   1. Within the UPF, UPF then removes the GTP-U header, processes the packet, and routes it over the N6 interface toward the destination (Internet, enterprise network, cloud services, etc.).

2. Downlink Data Flow

   * UPF receives incoming data in downlink direction at N6 interface (e.g. from the Internet).

   * The UPF encapsulates incoming data using GTP-U and forwards it over the N3 interface to the gNB. It maps traffic flows with different QoS requirements to different QoS treatments based on packet filters and QoS rules configured by SMF.

   * The gNB forwards the packets to the UE over the air-interface. UE-side modem stack then transparently passes the application packets to the app hosted on the UE.

In summary, the UPF is responsible for packet routing and forwarding, packet inspection and filtering, participating in subscriber and flow policy enforcement, inline services (NAT, firewall, DNS etc) and QoS handling.

6. Security Considerations

Security considerations are included separately in the SCONE protocol documents. Specific to the use case description in this document, there are no additional security considerations.

7. IANA Considerations

This document has no IANA actions.

8. References

8.1. Normative References

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