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Applicability & Manageability consideration for SCONE
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Abstract

This document addresses the applicability and manageability considerations involved in providing throughput advice to application endpoints in telecommunications service provider networks supporting the Standard Communication with Network Elements (SCONE) protocol.

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1. Introduction

The SCONE protocol is a signaling mechanism that enables on-path network elements to communicate the maximum allowable bit rate to application endpoints, with particular relevance to adaptive bit-rate applications. This document addresses the applicability and manageability considerations of deploying the SCONE protocol within telecommunications provider networks.

The SCONE protocol operates on the basis of a UDP 4-tuple. Network elements capable of rate limiting at this granularity can send notifications of the maximum allowable bit rate in each direction of the observed traffic. Such network elements may also drop or delay packets within the corresponding UDP 4-tuple flows. This implies an assumption that on-path network elements have certain capabilities: specifically, the ability to detect and maintain UDP 4-tuple flows, apply rate-limiting policies, and identify flows that include SCONE packets in order to insert throughput advice.

In this document, on-path network elements are generally considered within the `_access_` part of the telecommunications provider's network. However, their behavior may differ across `_access_` technologies. For example, a wireless access network element may operate differently from one in a fixed broadband network. Wi-Fi access networks represent another case, where enforcement is often per user or per Service Set Identifier (SSID), but visibility into UDP 4-tuples may be limited. Among the different access networks considered, mobile networks offer the most fine-grained visibility into traffic flows and can act at the individual flow level. In mobile networks, the User Plane Function (UPF) in 5G and the Packet Data Network Gateway (P-GW) in 4G can generate throughput advice to guide adaptive applications on a per-flow basis. In wireline broadband networks, by contrast, rate limiting is typically applied

at a centralized Broadband Network Gateway (BNG) or at aggregation points where multiple Customer Premises Equipment (CPE) devices connect.

Accordingly, applicability and manageability considerations must span a wide range of access-network scenarios, each of which handles per-flow rate limiting differently. This document first describes generic considerations for the SCONE protocol and then provides network-specific considerations where throughput advisory signaling can enhance both resource utilization and user experience.

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. Terminology

- * 4G - Fourth Generation mobile network technology, also known as Long-Term Evolution (LTE), defined by the 3rd Generation Partnership Project (3GPP).
- * 5G - Fifth Generation Mobile Networks The fifth generation of cellular mobile network technology defined by 3GPP.
- * Adaptive Bit-Rate (ABR) Video Video streaming technology that adjusts video quality dynamically based on network conditions.
- * BNG (Broadband Network Gateway) A network element that serves as the access point for subscribers in wireline broadband networks. It establishes and manages subscriber sessions, aggregates traffic from multiple subscriber access nodes, and routes this traffic to the service provider's core network. BNG functions include subscriber authentication, IP address assignment, policy enforcement, and quality of service management. It typically supports subscriber session protocols such as DHCP, PPPoE, or IPoE, and interacts with AAA and DHCP servers to enable secure and managed access to broadband services.
- * Client App The user-facing application running on an operating system, which receives network throughput advice.
- * Content Provider Entity or service that delivers media and data content accessed by end-users.

- * CPE - Customer Premise Equipment CPE refers to networking hardware located at the customer's site and used to connect to a service provider's network. Typical CPE includes routers, modems, or gateways that provide access and management for residential or enterprise services.
- * DHCP - Dynamic Host Configuration Protocol A network management protocol used to dynamically assign IP addresses and other configuration parameters to devices on a network, enabling automatic and centralized network configuration.
- * EPC - The Evolved Packet Core Is the all-IP core architecture for 4G/LTE, responsible for managing user sessions, mobility, and the integration of data and voice traffic over packet-switched networks.
- * EPS Bearer - Evolved Packet System Bearer In 4G LTE networks, an EPS bearer is a virtual transmission path with specific Quality of Service (QoS) parameters that carries user data between the User Equipment (UE) and the Packet Data Network Gateway (P-GW). The EPS bearer ensures end-to-end delivery of IP packets with particular handling characteristics, such as priority, latency, and guaranteed bit rate. There are two main types: the Default EPS Bearer which provides always-on best-effort connectivity, and Dedicated EPS Bearers configured for services with specialized QoS requirements, such as voice or video.
- * EPS Gateway In 4G LTE networks, the EPS Gateway primarily refers to the combination of the Serving Gateway (S-GW) and the Packet Data Network Gateway (P-GW). The Serving Gateway routes and forwards user data packets between the E-UTRAN access network and the Packet Data Network, acting as a mobility anchor during handovers. The Packet Data Network Gateway provides connectivity from the user equipment (UE) to external packet data networks, performing functions such as policy enforcement, charging, and lawful interception. Together, these gateways form the core user-plane interface of the Evolved Packet System (EPS).
- * gNB - Next Generation Node B 5G radio access network node connecting user equipment to the 5G core network.
- * IPoE IP over Ethernet A protocol that delivers IP packets directly over Ethernet without requiring a login or session establishment, commonly used in broadband networks in conjunction with DHCP for IP address assignment.
- * LTE - Long-Term Evolution 4G wireless broadband technology and related network architecture.

- * P-GW - Public Data Network Gateway Is the network function within the Evolved Packet Core (EPC) that provides connectivity between the user equipment and external packet data networks, such as the Internet.
- * PDU - Protocol Data Unit In 3GPP terminology, a PDU is a unit of information at a given protocol layer, such as an IP packet at the network layer. Specifically in 5G, a PDU Session represents a logical connection that carries one or more PDUs between the User Equipment (UE) and a Data Network (DN) through the User Plane Function (UPF). PDU Sessions support multiple types of PDUs, including IPv4, IPv6, Ethernet frames, and unstructured data, and are associated with one or more QoS Flows that define handling and quality requirements. The PDU framework is essential for managing application data transport and quality of service within the 3GPP system architecture.
- * PPP - Point-to-Point Protocol A data link layer communication protocol used to establish a direct connection between two nodes, commonly used for dial-up and broadband internet connections to provide authentication, encryption, and compression.
- * SCONE - Standard Communication with Network Elements Protocol allowing throughput or rate advice signaling from the network to application endpoints.
- * SMF - Session Management Function 5G network function that manages sessions and enforces policies.
- * UE - User Equipment The mobile device or endpoint used by the subscriber to access the network.
- * UPF - User Plane Function 5G core network element responsible for user-plane traffic routing and applying policy decisions.
- * Wireline Network Broadband network based on fixed infrastructure (e.g., DSL, cable, fiber).

4. Generic Applicability and Manageability considerations

4.1. Flow session awareness

SCONE signaling operates only over established sessions. Network elements MUST be able to unambiguously associate throughput advice with application flows. Each session is bound to an IP address and port, ensuring SCONE packets are routed precisely without affecting unrelated traffic.

4.2. Per-Flow Signaling

Throughput advice is applied on a per4-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.

4.3. QoS awareness

Networks can enforce Quality of Service (QoS) using various techniques. In some cases, operators may wish to apply separate QoS policies to SCONE-enabled flows. The network element that inserts SCONE advice does not need to interpret or enforce QoS policies directly—it only needs to provide the advice. However, the operator **SHOULD** be able to identify SCONE-enabled flows and apply differentiated QoS treatment when desired.

4.4. 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, allow the network to signal the maximum allowable bit rate, and reduce CPU overhead by eliminating additional classification steps.

4.5. 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.

4.6. 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. Network providers **MAY** define adjustable update intervals based on application requirements, network capacity, and operational constraints. The SCONE protocol specifies a minimum interval of 67 seconds between updates [Editor's Note: insert reference]

4.7. Dynamic Updates

Networks may enforce dynamic rate limits during active sessions due to:

- * Changes in access network type (requiring updated throughput advice)
- * Subscriber policy updates (e.g., exceeding usage thresholds)
- * Adjustments to maximum allowable throughput
- * Periodic refreshes of throughput advice (e.g., timers for maximum update periodicity)

In such cases, the network element SHOULD be able to initiate SCONE packets to provide updated advice, or applications should generate SCONE packets frequently enough to trigger network responses.

4.8. Monitoring and Logging

SCONE signaling can be integrated into existing operational and management 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 intended endpoints

4.9. Conformance Monitoring

Network elements providing SCONE throughput advice MAY implement mechanisms to measure compliance, either per application flow or in aggregate. This allows operators to validate advisory effectiveness and adjust policies.

4.10. Standards Compliance

SCONE signaling is expected to traverse the existing data path. For example, in 3GPP-compliant networks, SCONE packets are carried within Protocol Data Unit (PDU) sessions established between the User Equipment (UE) and Internet endpoints.

4.11. Interworking with Other Congestion Management Mechanisms

SCONE operates independently of transport-layer mechanisms such as Explicit Congestion Notification (ECN) or Low Latency, Low Loss, and Scalable throughput (L4S). Operators MAY harmonize multiple congestion signaling methods by policy or scope deployments to avoid conflicting feedback.

5. SCONE Usage in a 5G Network

5G systems are built on a cloud-native Service-Based Architecture (SBA), which provides flexibility for introducing new functions such as SCONE. The User Plane Function (UPF) serves as the natural anchor point for SCONE signaling because it handles packet forwarding, QoS enforcement, and interaction with the Session Management Function (SMF) and Policy Control Function (PCF).

5.1. Applicability of SCONE in a 5G Network

In 5G, the UPF is the on-path network element with access to subscriber policy and user-plane connectivity between the User Equipment (UE or client application endpoint) and the Internet. The UPF is capable of generating SCONE throughput advice per application flow, enabling endpoints to adjust sending rates proactively. SCONE signaling occurs over the existing data path. The following diagram illustrates how throughput advice is conveyed within 5G, highlighting the role of user-plane network elements.

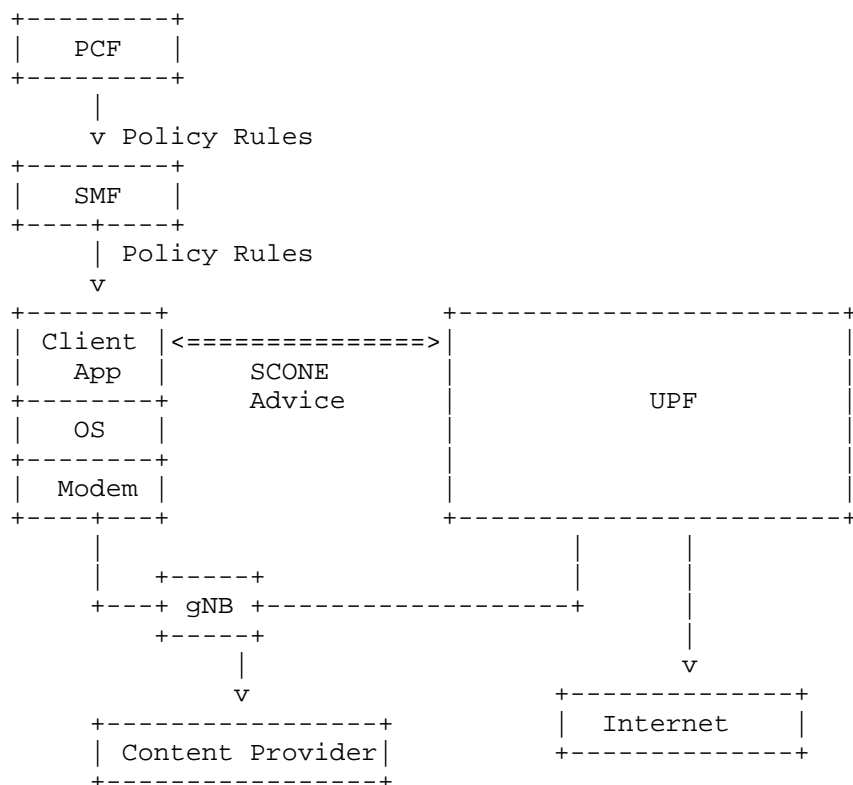


Figure 1: SCONE Integration within the 5G SA Network

5.2. 5G specific considerations

This section describes how the SCONE protocol can be deployed and managed within 3GPP [_5G-Arch] networks, including support for SCONE packets over established PDU sessions.

5.2.1. 3GPP Defined PDU Session Establishment Procedures

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

1. PDN Connection / PDU Session (5G)

A logical connection between the UE and the P-GW (4G) or UPF (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 with defined QoS characteristics. 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.

5.2.2. 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 an allocated IP address, ensuring SCONE packets are routed precisely without affecting unrelated traffic.

5.2.3. Per-Flow Signaling

Throughput advice is applied on a per4-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.

5.2.4. 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 so that congestion-control signaling is not degraded under high-load conditions.

5.2.5. 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 during mobility procedures.

Where advisory logic is stateful at the UPF, operators **SHOULD** provide synchronization mechanisms to avoid discontinuities.

5.2.6. SCONE Hint to the Network

SCONE-aware applications **MUST** provide hints to the UPF for a given 4-tuple. Such hints prevent unnecessary default rate-limiting and allow the network to generate the maximum allowable bit rate.

5.2.7. Retransmission of Advised Bit-Rate

Both UPF and applications **SHOULD** support retransmission or periodic re-sending of SCONE packets to ensure reliable delivery.

5.2.8. Dynamic Updates

Mobile networks can enforce dynamic rate limits during active sessions, for example on a per-bearer basis.

5.2.9. Operations Monitoring and Logging

Mobile operators may integrate SCONE signaling into existing operational and management 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.

6. SCONE Usage in a 4G/LTE Network

In LTE/Evolved Packet Core (EPC) systems as defined by 3GPP [_4G-Arch], SCONE can be integrated at the PDN Gateway (P-GW) or the Serving Gateway (S-GW). Unlike 5G, traffic granularity is bearer-based rather than per flow.

Below is an example diagram illustrating SCONE integration within the P-GW:

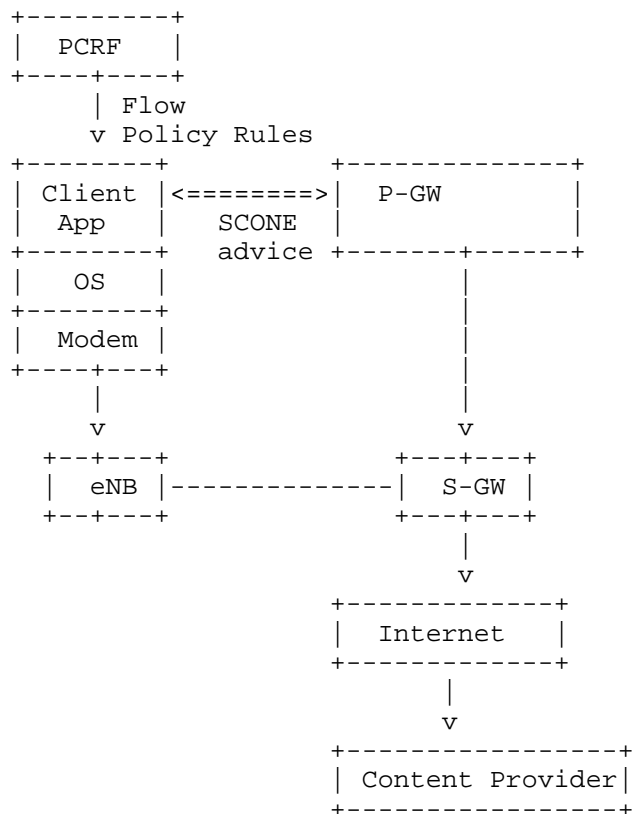


Figure 2: SCONE Integration within the 4G Network

6.1. Applicability of SCONE in a 4G/LTE Network

- * SCONE signaling maps to EPS bearers, enabling secure and targeted throughput advice between endpoints and EPC gateways.

6.2. 4G specific considerations

TBD

7. SCONE usage in a Wireline Network

SCONE can be deployed in wireline broadband networks at key access aggregation points such as Broadband Network Gateways (BNGs) or equivalent subscriber access nodes. These network elements originate throughput advice, signaling maximum sustainable data rates to application endpoints for each subscriber session, typically identified by DHCP, PPP, or IPoE session contexts.

Session granularity is typically based on subscriber sessions using PPP, DHCP, or IPoE protocols. Below is a high-level view of SCONE within the wireline network:

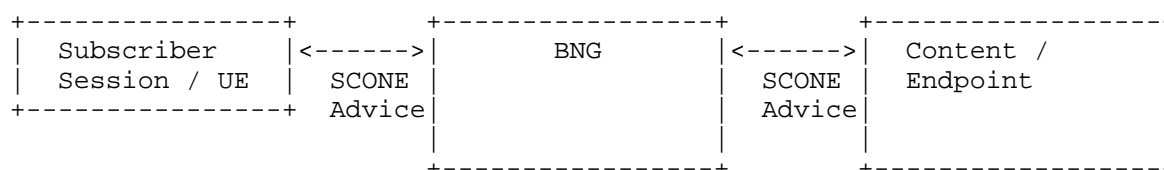


Figure 3: SCONE Integration within the Wireline Network

7.1. Wireline specific considerations

TBD

8. SCONE usage in a Wifi Networks

TBD

Editor's note : Home, enterprise and campus network have wifi access network. The SCONE client can be in the wifi network for the whole time of the session or there can be handover/offloading case where SCONE client can be moved from cellular network to wifi network or vice versa. The rate limit in such cases usually applied per user/device or SSIDs. This need to be covered in the considerations.

8.1. 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.

9. Security Considerations

Security considerations are included separately in the SCONE protocol documents.

10. IANA Considerations

This document has no IANA actions.

11. References

11.1. Normative

[RFC2119] [RFC8174]

11.2. Informative References

[_4G-Arch] [_5G-Arch]

12. References

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12.2. Informative References

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[_4G-Arch] 3GPP, "System architecture for the Evolved Packet Core (EPC)", 1 June 2020, <<https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=24300>>.

[_5G-Arch] 3GPP, "System architecture for the 5G System (5GS)", 7 January 2025, <<https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3144>>.

Appendix A. Appendix A. Additional Background details on role of UPF in 5G Mobile Packet Core

A.1. 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.

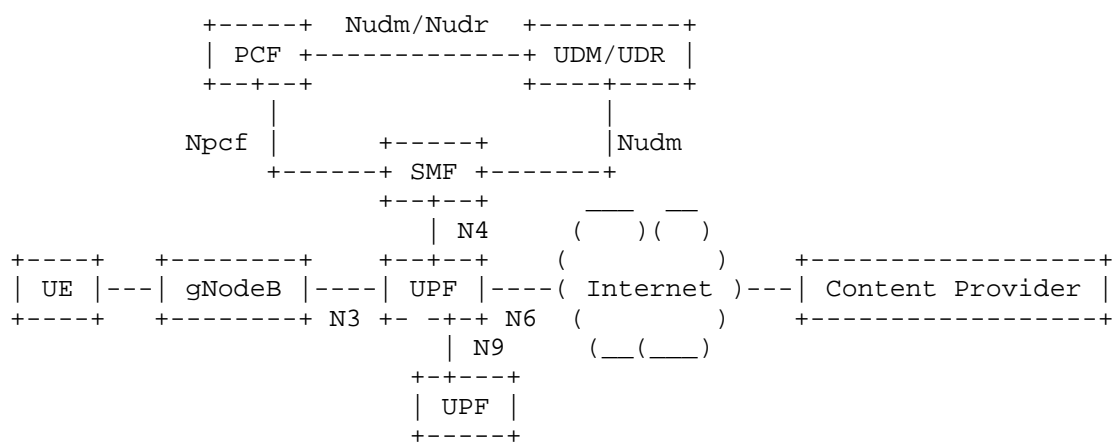


Figure 4: 5G Mobile Network Architecture

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.

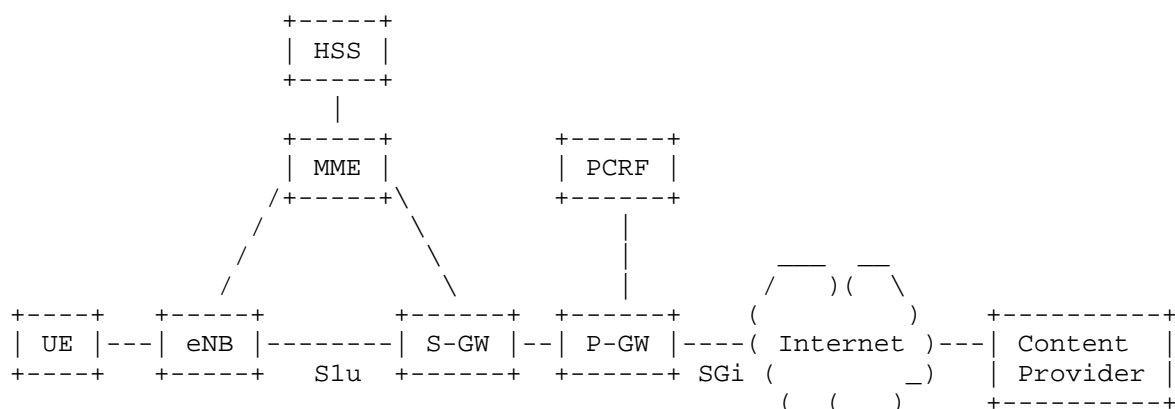


Figure 5: 4G Mobile Network Architecture

A.2. 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.

A.3. 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.

A.4. 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.

A.5. 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.

A.6. 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.

A.7. 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.

Appendix B. Appendix B. Non-ASCII Characters

This document uses the following kramdown-rfc character escapes for common non-ASCII symbols:

- * U+00A0 NO-BREAK SPACE → {nbsp}
- * U+00AD SOFT HYPHEN → {shy}
- * U+2011 NON-BREAKING HYPHEN → {nbhy}
- * U+200B ZERO WIDTH SPACE → {zwsp}
- * U+2060 WORD JOINER → {wj}
- * U+2013 EN DASH → {ndash}
- * U+2014 EM DASH → {mdash}
- * U+201C LEFT DOUBLE QUOTATION MARK → {ldquo}
- * U+201D RIGHT DOUBLE QUOTATION MARK → {rdquo}
- * U+2018 LEFT SINGLE QUOTATION MARK → {lsquo}
- * U+2019 RIGHT SINGLE QUOTATION MARK → {rsquo}
- * U+20AC EURO SIGN → {euro}

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