5G CORE NETWORKS

POWERING DIGITALIZATION

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CHAPTER 13

Network functions and services

This chapter describes in more detail the different network functions, reference points and services that are developed for 5GC. Before jumping into the actual descriptions, it may be useful to reiterate what we actually mean by a Network Function, a service and service based interfaces, as introduced in previous chapters.

With the adoption of cloud technologies and service based interfaces 3GPP has evolved the way the logical architecture is described. What was called a node or logical entity in EPS, e.g., the MME, is now called a Network Function e.g., the AMF. The reason for this change in terminology is to indicate that the Network Function is typically a set of software running on a cloud platform rather than an integrated product with dedicated HW.

The 5G Core Network Functions supports or hosts a collection of services and each Network Function offers one or more services to other Network Functions in the network. These services are made available over Service Based Interfaces in the Service Based Architecture (SBA). In practice this means that functionality supported in a specific Network Function is made available and accessible over an API.

The Network Functions that includes logic and functionality for processing of signaling are exposing and services making them available to other network functions. For each interaction between network functions, one of these acts as a "Service Consumer," and the other as a "Service Producer."

13.1 5G core network functions

13.1.1 AMF—Access and mobility management function

The AMF interacts with the access network over the N2 interface and with UEs over the N1 interface. Interactions with all other Network Functions are done via service-based interfaces. The AMF supports establishing encrypted signaling connections towards UEs, allowing these to register, to be authenticated, and to move between different radio cells in the network. The AMF also supports paging devices in idle mode.

When a UE is connected via one access network e.g., NG-RAN there is a single AMF that handles all the signaling interactions with the UE and via one N1 interface.

The AMF relays all session management-related signaling messages between the devices and the SMF Network Function. The AMF also relays SMS messages between the UEs and SMSF and it also relays location Services messages between UE and LMF as

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well as between RAN and LMF. Furthermore, the AMF relays UE policy messages between the PCF and the UE.

The AMF includes security anchor functionality supports the authentication and authorization of UEs (in cooperation with AUSF and UDM). After successful authentication the AMF derives separate sets of keys for integrity protection for the:

- N1 NAS signaling between UE and AMF.
- N2 RRC signaling between UE and NG-RAN.
- User Plane traffic between UE and eNB.

13.1.2 SMF—Session management function

The Session Management functionality of the 5G system has the responsibility for the setup of the connectivity for the UE towards Data Networks as well as managing the User Plane for that connectivity. The SMF is the control function that manages the user sessions including establishment, modification and release of sessions, and it can allocate IP addresses for IP PDU sessions. The SMF communicates indirectly with the UE through the AMF that relays session-related messages between the devices and the SMFs.

Compared to EPS the session management has added flexibility e.g., there are new options for end-user protocol types, different options for how to handle service and session continuity, as well as a flexible User Plane architecture.

The SMF interacts with other Network Functions through service based interfaces, and it also selects and controls the different UPF network functions in the network over the N4 network interface.

The SMF interacts with the PCF Network Function to retrieve policies which are used by the SMF to configure the UPF for the PDU session. Including configuration of the traffic steering in the UPF for individual sessions.

The SMF also collects charging data, and also controls the charging functionality in the UPF. The SMF supports both offline and online charging.

13.1.3 UPF—User plane function

The UPF processes and forwards user data. The functionality of the UPF is controlled by the SMF. It interconnects with external IP networks and acts as an anchor point for the UEs towards external networks, hiding the mobility. This means that an IP address of a specific UE PDU session is routable to the UPF that is serving this UE and Session.

The UPF performs various types of processing of the forwarded data. It generates charging data records and traffic usage reports. It can apply "packet inspection," analyzing the content of the user data packets for usage either as input to policy decisions, or as basis for the traffic reporting.

It also executes on various network or user policies, for example enforcing gating, redirection of traffic, or applying different data rate limitations.

When a device is in idle state and not immediately reachable from the network, any traffic sent towards this device is buffered by the UPF which triggers a page from the network to force the device back to go back to connected state and receive its data.

5G Core UPF can be deployed in series, e.g. one UPF distributed towards the edge of the network, and one UPF located in a more central network site. Network rules can then be used to control the traffic forwarding of the distributed UPF. Classification of data packets coming from the UE (uplink packets) can be applied to determine if the data should be sent out onto a local, distributed IP network, or if the packets are to be forwarded to the centralized UPF.

The UPF can also apply Quality-of-Service (QoS) marking of packets towards the radio network or towards external networks. This can be used by the transport network to handle each packet with the right priority in case of congestion in the network.

13.1.4 NRF—Network repository function

The NRF is a repository of the profiles of the network functions that are available in the network. The purpose of the NRF is to allow service consumer (e.g., an NF) to discover and select suitable service producers i.e., NFs and NF services without having to be configured beforehand.

When a new instance of a network function deployed or changed, e.g., due to scaling, the NRF is updated with the new profile information. The NRF profile can be updated by the network function itself or by another entity on behalf of the network function. There is also a keep alive mechanism that allows the NRF to maintain the repository and remove the profiles of missing or dormant network functions.

The NF profile in the NRF contains information like NF Type, address, capacity, Supported NF services and addresses for each NF service instance. The information is provided to the NF service consumer in the discovery procedure and provides to enough for information for the service consumer to use the service based interface of the selected NF and NF service.

The NRF profile also contains authorisation information and the NRF only provides the profiles to a consumer that can discover specific the network function or service.

13.1.5 UDM—Unified data management function

The UDM is a front-end for the user subscription data stored in the UDR.

The UDM uses subscription data that may be stored in UDR to execute application logic like access authorization, registration management and reachability for terminating event e.g., SMS.

When a UE attaches to the system the UDM authorizes the access and performs several checks of supported features, barring and restrictions due to e.g., roaming.

The UDM generates the authentication credentials that the AUSF use to authenticate UEs. It also manages permanent identity privacy and can be used by other entities to resolve the concealed permanent identity (SUCI) to the real permanent identity (SUPI).

Different instances of the UDM can be used for same user in different transactions.

The UDM also UDM keeps track of which the AMF instance that is serving a specific UE and also the SMF(s) that is serving it's PDU sessions.

13.1.6 UDR—Unified data repository

The UDR is the database where various types of data is stored. Important data is of course the subscription data and data defining various types of network or user policies. UDR storage and access to data is offered as services to other network functions, specifically UDM, PCF, and NEF.

13.1.7 UDSF—Unstructured data storage function

The UDSF is an optional function that allows other NFs to store dynamic context data outside the NF itself. This is sometimes referred to as a "stateless" implementation.

Unstructured data refers to data for which the structure is not defined in 3GPP specifications. Each vendor using a UDSF may impose it's own specific structure of the data stored in the UDSF and it is not expected that an NF from a different vendors can read and understand the stored data.

13.1.8 AUSF—AUthentication server function

The AUSF provides three services and is in the subscriber's home network. It is responsible for handling the authentication in the home network, based on information received from the UE and information retrieved from the UDM. It provides security parameters to protect Steering of Roaming information and it also provides security parameters to protect information in the UE Update procedure.

13.1.9 5G-EIR—5G equipment identity registry

The 5G-EIR is a network function that can check if the Permanent Equipment ID (an ID of the actual device hardware) has been blacklisted or not. This can for example be used by operators to block access to the network if the device has been stolen and blacklisted.

13.1.10 PCF—Policy control function

The PCF provides policy control for Sessions management related functionality, for access and mobility related functionality, for UE access selection and PDU Session selection related functionality and supports Negotiation of future background data transfers.

For session management related the PCF interacts with application functions and the SMF to provides authorized QoS and charging control for service data flows, PDU Session related policy control and event reporting for PDU sessions.

The PCF interacts with the AMF to for the access and mobility policy control that include management of service area restrictions and the management of the RFSP (Radio Frequency Selection Priority, a parameter used by NG-RAN to differentiate the treatment of different UEs).

The PCF also provides policy information to the UE (via the AMF). These polices include discovery and selection policies for non 3GPP networks, Session continuity mode selection policy, network slice selection policy, data network name selection policy and more.

13.1.11 NSSF—Network slice selection function

The NSSF selects the (set of) network slice instances for the UE and the set of AMFs that should serve the UE. The AMF may be dedicated to one or a set of network slices and the NSSF that knows of all slices I the network assist the AMF with cross slice selection functionality:

13.1.12 NEF—Network exposure function

The NEF has a similar role as the SCEF in EPS and supports exposure of event and capabilities from the 5G system towards applications and network functions inside and outside the operator's network.

The NEF can support monitoring of specific events in the 5G System and making these events available to authorized applications and network functions. Examples of event that can be made available in 3GPP Release 15 are location of UE, reachability, roaming status, and loss of connectivity.

The NEF can also support provisioning of foreseen UE behavioral information, this information can be further used in e.g., the AMF to tune the system and UE behaviour.

The NEF can in addition support external applications to manage for specific QoS and/or charging. It can be used by authorized applications to request specific QoS/priority handling for a session, and for setting applicable charging party or charging rate.

A single NEF may support a subset of the functionalities and there may be NEFs with different capabilities in one network.

13.1.13 NWDAF—Network data analytics function

The NWDAF is a function that can collect data, perform analytics and provide the results to other network functions. The network functions may adapt their behaviour based on the reported results from the NDWAF. In 3GPP Release 15 the NWDAF is somewhat limited and only provides network slice data analytics (network slice load level

information). The PCF and NSSF can consume network analytics from the NWDAF and e.g., NSSF may use the network slice load level information for slice selection.

13.1.14 SEPP—Security edge protection proxy

The SEPP is a non-transparent proxy that is used to protect the signaling between operators in roaming scenarios. The SEPP acts as a relay between the Service Producer and the Service Consumer and it hides the network topology from other operators and it supports Message filtering and policing.

13.1.15 N3IWF—Non-3GPP inter working function

The non-3GPP interworking function (N3IWF) is used for integrating non-3GPP accesses with the 5G core. It is used for non-3GPP access types such as WiFi and fixed. The N3IWF terminates the IKEv2 and IPsec protocols that is used towards the UE over NWu and relays the information needed to authenticate the user equipment and authorize its access to the 5G core over the N2 interface. It is connected to the 5G Core via the N2 and N3 interfaces for the control and user planes, respectively.

13.1.16 AF—Application function

The AF is a 3GPP representation of applications either inside outside the operator's network that interacts with the 3GPP Core Network. Applications may interact and influence some aspects of the 5G core. Applications may influence traffic routing (e.g., an edge computing application), they may access the exposure function interact with the PCF to influence QoS and charging policies.

Applications considered trusted by an operator may be allowed to interact directly with relevant Network Functions. Other Applications may use the external exposure framework via the NEF to interact with relevant Network Functions.

13.1.17 SMSF—Short message service function

The SMSF supports delivery of SMS between the UE and the 5G Core (via the AMF). The SMSF is responsible for checking subscription checking and terminates the SMS protocols (SM-RP/SM-CP) used for communication with the UE. The AMF provides access to the NAS connection to the UE as a service to the SMSF on top of which the SM-RP/SM-CP messages are transferred.

13.1.18 LMF—Location management function

The LMF provides functionality to determine the location of a UE. The LMF can retrieve location estimated from the UE and it can retrieve location measurements and other data from NG-RAN. Based on retrieved data, subscription and privacy checks the LMF can determine and provide the location of UEs to other NFs. To reach the UE

and the NG-RAN the LMF uses services from the AMF to access to the NAS connection to the UE and the N2 connection NG-RAN respectively.

13.2 Services and service operations

The 5G Core Network Functions offers their capabilities to other 5G Core network functions as NF services, which are accessed through service based interfaces i.e., Restful APIs. The focus of the specifications is to define the behaviour of service producers and leave flexibility for the service consumers in order to allow reuse of services when relevant and possible. A simplified picture of the service in 5GC is shown in Fig. 13.1.

More details of the services described in the following chapters can be found in 3GPP TS 23.502, 3GPP TS 23.503, and 3GPP TS 33.501.

13.2.1 AMF services

The AMF acts as a service producer for four services Namf_Communication, Namf_EventExposure Namf_MT, and Namf_Location as shown in Fig. 13.2.

The Namf_Communication service is the main service of the AMF and it has numerous Service Operations. For example, the Namf_Communication service enables other NFs like the SMF and PCF to communicate with the UE and/or the NG-RAN through the AMF. It allows new AMFs to retrieve the UE context at mobility. It also allows subscription to status changes and has an operation that allows the SMF to request Bearer Identities.

The Namf_MT service allows other NFs make sure the UE is reachable. The Namf_Location allows other NFs to request location information for a UE. Namf_EventExposure allows other NFs subscribe to notifications of mobility related events and statistics in the AMF.

13.2.1.1 Namf_Communication service

The Namf_Communication service enables an NF to communicate with the UE through N1 NAS messages or to communicate with NG-RAN or other access networks.

Namf_Communication_UEContextTransfer service operation

The Namf_Communication_UEContextTransfer request is used by an AMF to retrieve the UE context from another AMF, it's e.g., used when a UE registers in a different AMF. The new AMF can use the service operation to pass an integrity protected message that it receives from the UE to the old AMF. The old AMF use the integrity protection to verify that the new AMF has received the message from a UE using the credentials from the old AMF. If successfully verified, the AMF provides UE context to the new AMF in the Namf_Communication_UEContextTransfer response.

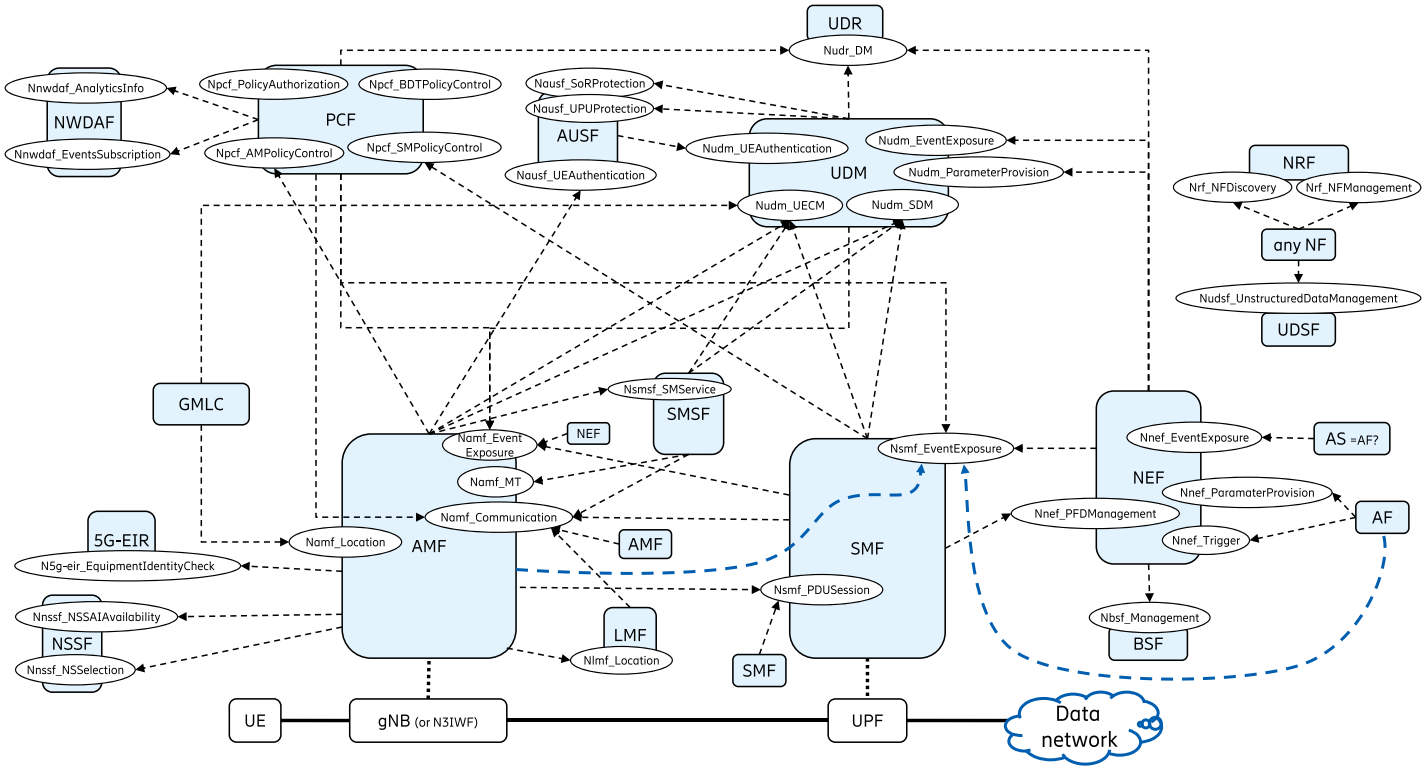

Fig. 13.1 Simplified overview of services in 5GC.

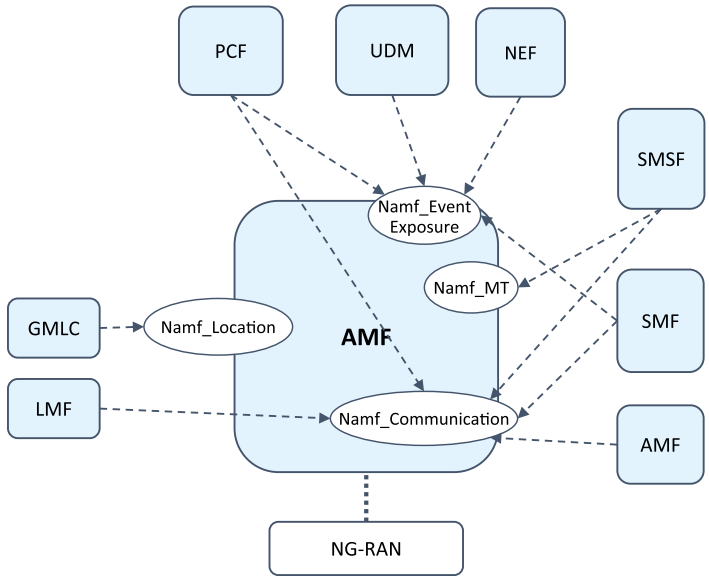

Fig. 13.2 AMF services.

Namf_Communication_RegistrationCompleteNotify service operation

The Namf_Communication_RegistrationCompleteNotify service operation is used by a new AMF to inform the old AMF that a UE context transfer succeeded and that the UE is now successfully registering with the new AMF. The old AMF marks the UE context as inactive.

The new AMF sends a Namf_Communication_RegistrationCompleteNotify acknowledgment to the consumer NF. The AMF is notified whether the AM Policy Association Information in the UE context will be used or not (i.e., new AMF may select a different PCF and then create a new AM Policy Association).

Namf_Communication_N1MessageSubscribe service operation

The Namf_ Communication_N1MessageSubscribe enables an NF e.g., SMSF to subscribe to the AMF to get notified of a particular N1 message type from the UE.

When an NF subscribes with the Namf_Communication_N1MessageSubscribe service operation the AMF checks. If the NF is allowed to subscribe to the requested N1 message type and stores a binding for the NF to deliver uplink N1 NAS messages, of the requested type, with the Namf_Communication_N1MessageNotify service operation.

Namf_Communication_N1MessageNotify service operation

The Namf_Communication_ N1MessageNotify service operation is used to pass uplink N1 NAS messages from the UE to an NF. The receiving NF has either explicitly subscribed to receiving the N1 NAS message type or the NF type is known to known to consume the received message type.

Namf_Communication_N1MessageUnSubscribe service operation

To stop receiving notifications from an AMF an NF can use the Namf_Communication_N1MessageUnSubscribe service operation.

Namf_Communication_N1N2MessageTransfer service operation

The Namf_Communication_N1N2MessageTransfer service operation can be used by NFs to transfer downlink N1 messages to the UE or N2 message to NG-RAN through the AMF.

If there is no active N1 or N2 connection (i.e., UE is in CM-IDLE state) the AMF need to invoke the network triggered service request procedure to page the UE and re-establish the N1 and N2 connection.

If there are N1 and N2 connections available the AMF sends the message to the UE and/or NG-RAN according to the request and responds to the requesting NF, with a Namf_Communication_N1N2MessageTransfer response, providing an indication of whether the transfer the N1 and/or the N2 message towards the UE and/or the NG-RAN was successful. Note that this means that the message has been sent from the AMF and it is not guaranteed that it is successfully received by UE or NG-RAN.

By including the N1N2TransferFailure Notification Target Address in the Namf_Communication_N1N2MessageTransfer service operation the requesting NF is implicitly subscribed to be notified of any transfer failures. When AMF detects that the UE fails to response to paging, the AMF invokes the Namf_Communication_N1N2TransferFailureNotification.

Namf_Communication_N1N2TransferFailureNotification service operation

The AMF uses the Namf_Communication_N1N2TransferFailureNotification service operation to notify an NF, that earlier initiated an Namf_Communication_N1N2MessageTransfer service operation, that the AMF failed to deliver the N1 message to the UE as the UE failed to respond to paging.

Namf_Communication_N2InfoSubscribe service operation

An NF can use the Namf_Communication_N2InfoSubscribe service operation to subscribe to N2 messages from NG-RAN of a specific type. The AMF creates a binding for the requesting NF and the requested N2 message type.

Namf_Communication_N2InfoUnSubscribe service operation

An NF can use the Namf_Communication_N2InfoUnSubscribe service operation to unsubscribe to N2 messages from NG-RAN. The AMF deletes the binding for the requesting NF and the requested N2 message type.

Namf_Communication_N2InfoNotify service operation

The AMF uses the Namf_Communication_N2InfoNotify service operation to send N2 message information to an NF that has subscribed to the particular N2 messages. This service operation is also used to redirect N2 messages to a new AMF that is currently serving the UE.

Namf_Communication_CreateUEContext service operation

The Namf_Communication_CreateUEContext service operation is used by a source AMF to create a UE context in a target AMF during handover procedures. The UE context information transferred from the source AMF to the target AMF includes key parameters needed by the new AMF like the 5G-GUTI, SUPI, DRX parameters, AM policy information, PCF ID, UE network capability, N1 security context information, event subscriptions by other consumer NF, and the list of SM PDU Session IDs along with the SMF handling the PDU Session.

Namf_Communication_ReleaseUEContext service operation

The Namf_ Communication_ReleaseUEContext service operation is used by a source AMF to release the UE context in a target AMF in case the handover fails and the handover cancel procedures are invoked.

Namf_Communication_EBIAssignment service operation

An SMF can use the Namf_Communication_EBIAssignment service operation to request and release EPS Bearer IDs (EBIs). EBIs are not needed in 5GS but they are needed to retain the bearers when performing inter system HO from 5GS to EPS. Since there is a limited number of bearers supported in EPS the AMF coordinates the allocation of EBIs since there may be several PDU sessions with in different SMFs for each UE.

The SMF invokes the Namf_Communication_EBIAssignment service operation when it determines that one or more EPS Bearer IDs are required for EPS QoS mapping for a PDU Session. The AMF uses the QoS parameters and the S-NSSAI to prioritize the EBI request.

If the SMF determines that some EBIs are not needed, the consumer NF indicates the EBI(s) that can be released in the Released EBI list.

Namf_Communication_AMFStatusChangeSubscribe service operation

The Namf_Communication_AMFStatusChangeSubscribe service operation is used by peer NFs to subscribe to updates of the AMF status e.g., if the AMF becomes unavailable or no longer serve the indicated GUAMI(s). The peer NFs (SMF, UDM, PCF) can use this service to detect if a GUAMI is served by a different AMF in case a group.

Namf_Communication_AMFStatusChangeUnSubscribe service operation

The Namf_Communication_AMFStatusChangeUnSubscribe service operation is used by an NF to unsubscribe for AMF status change notification.

Namf_Communication_AMFStatusChangeNotify service operation

The Namf_Communication_AMFStatusChangeNotify service operation report AMF Status change (e.g., AMF unavailable) notification to NFs that has previously registered with the AMF using the Namf_Communication_AMFStatusChangeSubscribe service operation.

The notify message includes the GUAMI(s) impacted by the status change and it may also include an alternative AMF that can serve the GUAMI instead.

13.2.1.2 Namf_EventExposure service

The Namf_EventExposure service allows NFs to subscribe and get notified about AMF events. The Namf_EventExposure service has three service operations Namf_EventExposure_Subscribe, Namf_EventExposure_UnSubscribe and Namf_EventExposure_Notify.

The AMF can expose information about UE related events like:

- Location changes
- Time zone changes
- Access Type changes
- Registration state changes
- Connectivity state changes
- UE loss of communication
- UE reachability status

Event filter can be used by the requesting NF to narrow down the specific event of interest. For example, if the requesting NF is interested in knowing when a UE moves in and out of a specific tracking area it can subscribe to the location event and specify an event filter for the parameter tracking area and a specific tracking area ID value.

Namf_EventExposure_Subscribe service operation

The requesting NF can use the Namf_EventExposure_Subscribe service operation to subscribe to, or modify, event reporting for one UE, a group of UEs or all UEs I the AMF.

The requesting NF provides the target UEs, the Event IDs and associated Event filters and in addition, a Notification Correlation ID. The target UE(s) may be identified by SUPI(s), Internal Group ID or an indication that the AMF should report for all UEs.

When the AMF accepts the subscription, it responds with a Subscription Correlation ID that is used for managing or removing the subscription and possibly an expiry time for the subscription indicating when the AMF will stop further reporting. The AMF may also include a first event report, if available.

In the case that the requesting NF subscribes on behalf of another NF, the NF includes a Notification Target Address and correlation information for each of the Event IDs that should be notified directly to another NF.

If the requesting NF needs to modify a subscription, that it has previously created, it invokes Namf_EventExposure_Subscribe service operation with the Subscription Correlation ID and provides updated Event Filters with Event ID(s) to the AMF.

Namf_EventExposure_UnSubscribe service operation

An NF can use the Namf_EventExposure_UnSubscribe service operation to stop further event reporting for previously subscribed events. The Subscription Correlation ID that was received when subscribing to the event reporting is used as an input to the AMF to identify the specific events to stop reporting for.

Namf_EventExposure_Notify service operation

When the AMF detects an event corresponding to a subscription, it invokes the Namf_EventExposure_Notify service operation, for each subscribed NF that matches the event and event filter. The AMF includes information like AMF ID, Notification Correlation Information, Event ID, corresponding UE (SUPI and if available GPSI) and time stamp. The Notification Target Address and Notification Correlation ID helps the Receiving NF identify the event notification subscription. In addition, the AMF also included event specific parameter that indicates the type of event that has occurred and related information, e.g., Registration Area Update in new Registration Area.

13.2.1.3 Namf_MT service

The Namf_MT service allows an NF the service to make sure the UE is reachable to send e.g., MT SMS to a UE. The Namf_MT service also has a service operation that allows an NF to retrieve information to assist in terminating domain selection for IMS voice services.

Namf_MT_EnableUEReachability service operation

An NF can use the Namf_MT_EnableUEReachability service operation to request UE reachability from the AMF. This service operation is typically used by the SMSF to make sure the UE is ready to receive and SMS via the N1 NAS connection to the AMF.

If UE is in CM-CONNECTED state, the AMF responds to the requesting NF immediately. If the UE is in CM-IDLE state, the AMF may page the UE and respond to the consumer NF after the UE enters CM-CONNECTED state.

If paging fails and the UE is not reachable the AMF informs the requesting NF about the failure. If the AMF no longer serves the UE but the AMF knows which AMF that is serving the UE, the AMF provides redirection information which can be used by the NF consumer to retry vie the new AMF.

Namf_MT_ProvideDomainSelectionInfo service operation

The Namf_MT_ProvideDomainSelectionInfo service operation can be used by UDM to retrieve information that it can use to enhances the probability of reaching the UE with voice sessions.

When invoking the service operation UDM provides the SUPI of the UE and the AMF responds with an Indication of support for IMS voice over PS Session or not, Time stamp of the last radio contact with the UE and Current RAT type.

13.2.1.4 Namf_Location service

This Namf_Location service enables an NF to request location information for a target UE. The following are the key functionalities of this NF service.

- Allow NFs to request the current geodetic and optionally civic location of a target UE.
- Allow NFs to be notified of event information related to emergency sessions.
- Allow NFs to request Network Provided Location Information (NPLI) and/or local time zone corresponding to the location of a target UE.

Namf_Location_ProvidePositioningInfo service operation

The Namf_Location_ProvidePositioningInfo is typically triggered by the GMLC to request the position of a UE. The SUPI or PEI of the UE is provided as input to the Service operation and the response from the AMF includes positioning information for the UE e.g., Geodetic Location, Civic Location, Position Methods Used, Failure Cause.

To provide the positioning information the AMF may in turn use the Nlmf_Location_DetermineLocation service operation from the LMF that can trigger UE positioning procedures and provide positioning information.

Namf_Location_EventNotify service operation

The Namf_Location_EventNotify Service Operation is currently used to inform the GMLC of an emergency session and provides any UE location available to the AMF. It is also used to inform the GMLC when the emergency session has been released.

Namf_Location_ProvideLocationInfo service operation

The Namf_Location_ProvideLocationInfo service operation is typically used by the UDM to retrieve Network Provided Location Information of a target UE. The UE is identified by a SUPI and the AMF provides the available location information e.g., Cell Identity, Tracking Area Identity, Geographical/Geodetic Information, Current RAT Type, Local Time Zone.

13.2.2 SMF services

The SMF provides two services the Nsmf_PDUSession service and the Namf_EventExposure service as shown in Fig. 13.3. The Nsmf_PDUSession service provides

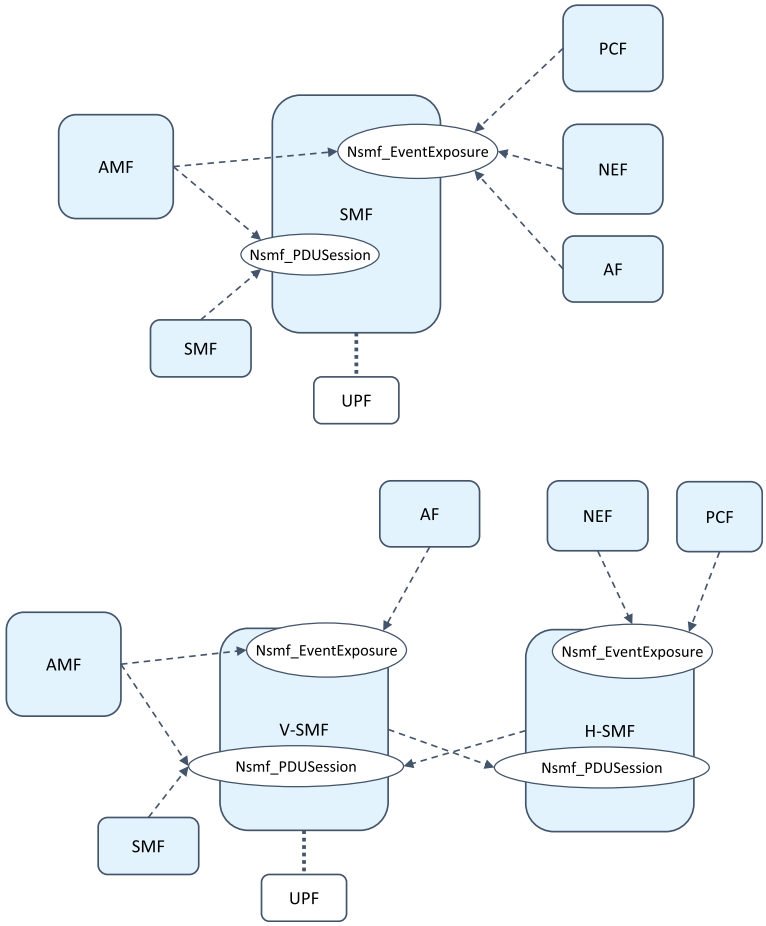

Fig. 13.3 SMF services.

the ability to manage PDU sessions and the Namf_EventExposure service provides the possibility to expose events from the SMF.

13.2.2.1 Nsmf_PDUSession_CreateSMContext service operation

The Nsmf_PDUSession_CreateSMContext service operation is used by the AMF to creates an AMF-SMF association to support a PDU Session. The AMF provides the SUPI, DNN, AMF ID and other parameters needed by the SMF to create the PDU session including the N1 SM message from the UE.

The SMF responds with a SM Context ID, PDU Session ID and any N1 SM messages for transfer to the UE and/or N2 messages to be transferred to the NG-RAN.

13.2.2.2 Nsmf_PDUSession_UpdateSMContext service operation

The Nsmf_PDUSession_UpdateSMContext service operation allows the AMF to update the AMF-SMF association to support a PDU Session and/or to provide SMF with

N1 or N2 SM information received from the UE or from the NG-RAN. The AMF includes the SM Context ID to identify the context in the SMF and N1 SM message, N2 message information or other parameters depending on the reason for update request.

13.2.2.3 Nsmf_PDUSession_ReleaseSMContext service operation

The Nsmf_PDUSession_ReleaseSMContext service operation is used by the AMF to release the AMF-SMF association when the PDU Session is being released.

13.2.2.4 Nsmf_PDUSession_SMContextStatusNotify service operation

The Nsmf_PDUSession_SMContextStatusNotify service operation is used by the SMF to notify the AMF when a PDU session is released (by e.g., the SMF or PCF) or when a PDU Session is handed over to a different system or access type.

13.2.2.5 Nsmf_PDUSession_Create service operation

The Nsmf_PDUSession_Create service operation is used in roaming scenarios between the V-SMF in the serving PLMN and H-SMF in the home PLMN. The Nsmf_PDUSession_Create Service Operation is triggered by the V-SMF because of the AMF invoking the Nsmf_PDUSession_CreateSMContext service operation to the V-SMF. The Nsmf_PDUSession_Create service operation is used to create a new PDU Session in the H-SMF or to create an association with an existing PDN connection in the home PGW-C+SMF.

The V-SMF SM Context ID in the input provides addressing information allocated by the V-SMF (to be used for service operations towards the V-SMF for this PDU Session).

13.2.2.6 Nsmf_PDUSession_Update service operation

The Nsmf_PDUSession_Update service operation is used between the V-SMF and H-SMF in roaming scenarios to Update the established PDU Session.

This service operation is invoked by the V-SMF towards the H-SMF in case the AMF has invoked the Nsmf_PDUSession_UpdateSMContext towards the V-SMF due to a UE or serving network requested PDU Session Modification. The Nsmf_PDUSession_Update Service Operation can also be used by the V-SMF to inform the H-SMF the access type changes are allowed for the PDU session.

The H-SMF invokes the Nsmf_PDUSession_Update Service Operation towards the V-SMF for UE and HPLMN initiated PDU Session Modifications and PDU Session Release to transfer SM PDU Session Modification request or SM PDU Session Release request messages to the UE. The service operation can also be used by the H-SMF towards the V-SMF to release resources e.g., during handover to EPS and.

13.2.2.7 Nsmf_PDUSession_Release service operation

The Nsmf_PDUSession_Release service operation is used in roaming scenarios by V-SMF to request the H-SMF to release the PDU Session and related resources during serving network initiated PDU Session release cases (e.g., implicit De-registration of UE in the serving network).

13.2.2.8 Nsmf_PDUSession_StatusNotify service operation

The Nsmf_PDUSession_StatusNotify Service Operation service operation is used in roaming scenarios by the H-SMF to notify V-SMF of changes to the status of a PDU Session e.g., PDU Session is released or handed over to EPS or a different access type.

13.2.2.9 Nsmf_PDUSession_ContextRequest service operation

The Nsmf_PDUSession_ContextRequest service operation is used by the AMF to fetch the SM Context during handover to EPS.

13.2.2.10 Nsmf_EventExposure service

The Nsmf_EventExposure service allows NFs to subscribe and get notified about events related to PDU sessions. The Nsmf_EventExposure service has three service operations Nsmf_EventExposure_Subscribe, Nsmf_EventExposure_UnSubscribe and Nsmf_EventExposure_Notify.

The SMF can expose information about PDU session related events like:

- UE IP address or Prefix change.
- PDU Session Release.
- UP path change.
- Change of Access Type.
- PLMN change.

Event filter can be used by the requesting NF to narrow down the specific event of interest. Event Filters specify the conditions to meet for triggering notification and can include one or more Parameters and the values that each parameter should match to trigger a notification.

The target of SMF event reporting may correspond to a single PDU Session ID, a UE ID an Internal Group Identifier or all UE on a specific DNN.

Nsmf_EventExposure_Subscribe service operation

The requesting NF can use the Nsmf_EventExposure_Subscribe service operation to subscribe to, or modify, event reporting for one UE, a group of UEs or all UEs I the SMF.

The requesting NF provides the target UEs, the Event IDs and associated Event filters and in addition, a Notification Correlation ID. The target UE(s) may be identified by SUPI(s), Internal Group ID or an indication that the SMF should report for all UEs.

When the SMF accepts the subscription, it responds with a Subscription Correlation ID that is used for managing or removing the subscription and possibly an expiry time for the subscription indicating when the SMF will stop further reporting. The AMF may also include a first event report, if available.

In the case that the requesting NF subscribes on behalf of another NF, the NF includes a Notification Target Address and correlation information for each of the Event IDs that should be notified directly to another NF.

If the requesting NF needs to modify a subscription, that it has previously created, it invokes Nsmf_EventExposure_Subscribe service operation with the Subscription Correlation ID and provides updated Event Filters with Event ID(s) to the SMF.

Nsmf_EventExposure_UnSubscribe service operation

An NF can use the Nsmf_EventExposure_UnSubscribe service operation to stop further event reporting for previously subscribed events. The Subscription Correlation ID that was received when subscribing to the event reporting is used as an input to the SMF to identify the specific events to stop reporting for.

Nsmf_EventExposure_Notify service operation

When the SMF detects an event corresponding to a subscription, it invokes the Nsmf_EventExposure_Notify service operation, for each subscribed NF that matches the event and event filter. The SMF includes information like SMF ID, Notification Correlation Information, Event ID, corresponding UE (SUPI and if available GPSI) and time stamp. The Notification Target Address and Notification Correlation ID helps the Receiving NF identify the event notification subscription. In addition, the SMF also included event specific parameter that indicates the type of event that has occurred and related information, e.g., Registration Area Update in new Registration Area.

13.2.3 PCF services

The PCF acts as a service producer for six services Npcf_AMPolicyControl, Npcf_Policy Authorization, Npcf_SMPolicyControl, Npcf_BDTPolicyControl, Npcf_UEPolicyControl, and Npcf_EventExposure, see Fig. 13.4.

The Npcf_AMPolicyControl service provides Access Control, network selection and Mobility Management related policies and UE Route Selection Policies to the AMF.

The Npcf_Policy Authorization authorizes and creates policies on request from an AF related to the PDU Session to which the AF session is bound to.

The Npcf_SMPolicyControl provides PDU session related policies to the SMF.

The Npcf_BDTPolicyControl, PCF service provides background data transfer policy to the NEF.

The Npcf_UEPolicyControl This PCF service provides the management of UE Policy Association to the NF consumers.

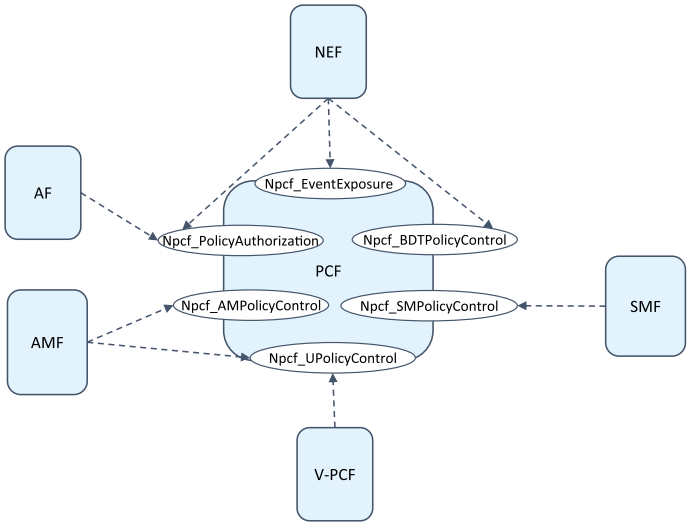

Fig. 13.4 PCF services.

The Npcf_EventExposure allows other NFs subscribe to notifications of PCF related events.

13.2.3.1 Npcf_AMPolicyControl service

The Npcf_AMPolicyControl service allows the AMF to create modify and delete per UE AM Policy Associations with the PCF. The PCF may provide the AMF with policy information per UE can may contain access and mobility related policy information as well as Policy Control Request Trigger conditions.

When the AMF detects that a Policy Control Request Trigger condition is met is will contact the PCF that may provide updated access and mobility related policy information and Policy Control Request Trigger conditions.

The Npcf_AMPolicyControl service also allows the PCF to send new AM policies for an established AM Policy Association.

Npcf_AMPolicyControl_Create service operation

The Npcf_AMPolicyControl_Create service operation allows the AMF to request the creation of an AM Policy Association with the PCF for a UE. When the PCF has created the AM Policy Association, the PCF may provide access and mobility related policy information and Policy Control Request Trigger conditions.

Npcf_AMPolicyControl_Update service operation

The AMF can use the Npcf_AMPolicyControl_Update service operation to request updated Policy information for a UE when a policy control request trigger is met, or

the AMF is changed (due to mobility) but the same PCF is used. The AMF will include policy control trigger condition(s) that have been met in the request.

Npcf_AMPolicyControl_UpdateNotify service operation

The Npcf_AMPolicyControl_UpdateNotify service operation allows the PCF, at any time, to provide the AMF with updated access and mobility related Policy information for an AM Policy Association. This notification can be sent by the PCF to the AMF without prior explicit subscription. The creation of the AM policy association is used as an implicit subscription that allows the PCF to send the notifications to the AMF.

Npcf_AMPolicyControl_Delete service operation

The Npcf_AMPolicyControl_Delete service operation enables the AMF to remove the AM Policy Association. When the AMF initiates the AM Policy Association Termination procedure the PCF deletes the AM Policy Association for this SUPI. This service operation is for example used at UE deregistration.

13.2.3.2 Npcf_PolicyAuthorization service

Th Npcf_PolicyAuthorization service is used to authorize an AF request and to create policies as requested by the authorized AF for the PDU Session to which the AF session is bound. This service also allows the NF consumer to subscribe/unsubscribe the notification of events.

Npcf_PolicyAuthorization_Create service operation

The Npcf_PolicyAuthorization_Create service operation is invoked by an AF towards a PCF and allows the PCF to authorize the request, create an application session and optionally determine and install policies according to the information provided by the AF. To identify the application session the AF provides the IP address of the UE and additional information e.g., UE identity, Media type, Media format, bandwidth requirements, flow description and/or Application identifier or traffic filtering information. The PCF responds to the AF with the application context and an application session ID that is used to identify the application context subsequent service operations for the same application session.

If the PCF determines that an SM policy should be installed or updated due the AF request it can use the Npcf_SMPolicyControl service towards the SMF to install or modify the policies according to the AF request.

Npcf_PolicyAuthorization_Update service operation

The Npcf_PolicyAuthorization_Update service operation allows the AF to update an established application session. The AF provides the application session ID and new service information to the PCF. The PCF Provides updates an application context in with

the accepted service information and use the Npcf_SMPolicyControl service to install any new the policies in the SMF. The PCF responds to the AF with an updated application context.

Npcf_PolicyAuthorization_Delete service operation

The Npcf_PolicyAuthorization_Delete Service Operation allows the AF to remove the application session and remove the application context in the PCF.

Npcf_PolicyAuthorization_Notify service operation

The Npcf_PolicyAuthorization_Notify service operation enables the PCF to notify an AF about events related to the application session. The PCF can inform the AF about events as outlined in the Npcf_PolicyAuthorization_Subscribe service operation below.

The PCF notifies the AF with an Event ID and Notification Correlation Information (information that enables the AF to identify the application session).

Npcf_PolicyAuthorization_Subscribe service operation

The Npcf_PolicyAuthorization_Subscribe service operation allows the AF to subscribe the notification of events related to applications sessions. The PCF supports event reporting to events like:

- Notification about application session context events.
- Notification about application session context termination.
- Notification about Service Data Flow QoS notification control.
- Notification about service data flow deactivation.
- Reporting usage for sponsored data connectivity.
- Notification of resources allocation outcome.

The AF includes one or more Event ID(s) as for events as listed above, information identifying the AF session e.g., UE IP address or SUPI, Notification Target Address and Notification Correlation ID.

The PCF responds with a Subscription Correlation ID when accepting the subscription. The AF can use the Subscription Correlation ID to refer to the subscription if it later wishes to modify or delete the subscription.

Npcf_PolicyAuthorization_Unsubscribe service operation

The Npcf_PolicyAuthorization_Unsubscribe service operation allows the NF to unsubscribe to notification of PCF events related to Npcf_PolicyAuthorization_Subscribe operation. The AF provides the Subscription Correlation information to the PCF so it can identify and remove the event subscription.

13.2.3.3 Npcf_SMPolicyControl service

The Npcf_SMPolicyControl service allows the SMF to create modify and delete per UE SM Policy Associations with the PCF. The PCF may provide the SMF with policy information per UE that may include PDU session related policy information as well as Policy Control Request Trigger conditions.

When the SMF detects that a Policy Control Request Trigger condition is met is will contact the PCF that may provide updated PDU session related policy information and Policy Control Request Trigger conditions.

The Npcf_SMPolicyControl service also allows the PCF to send new PDU Session policies for an established SM Session Policy Association.

Npcf_SMPolicyControl_Create service operation

The Npcf_SMPolicyControl_Create service operation allows the SMF to request the creation of an SM Policy Association with the PCF for a UE. When the PCF has created the SM Policy Association, the PCF may provide PDU Session related policy information and Policy Control Request Trigger conditions.

Npcf_SMPolicyControl_UpdateNotify service operation

The Npcf_SMPolicyControl_UpdateNotify service operation allows the PCF, at any time, to provide the SMF with updated PDU session related Policy information for an SM Policy Association. This notification can be sent by the PCF to the SMF without prior explicit subscription. The creation of the SM policy association is used as an implicit subscription that allows the PCF to send the notifications to the SMF.

Npcf_SMPolicyControl_Delete service operation

The Npcf_SMPolicyControl_Delete service operation enables the SMF to remove the SM Policy Association. When the SMF initiates the SM Policy Association Termination procedure the PCF deletes the SM Policy Association for this SUPI. This service operation is for example used at UE deregistration.

Npcf_SMPolicyControl_Update service operation

The SMF can use the Npcf_SMPolicyControl_Update service operation to request updated Policy information for a UE when a policy control request trigger is met. The SMF will include policy control trigger condition(s) that have been met in the request. The PCF may respond with provide updated policy information to the SMF.

13.2.3.4 Npcf_BDTPolicyControl service

The Npcf_BDTPolicyControl service provides background data transfer policy, which includes the following functionalities:

- Get background data transfer policies based on the request via NEF from AF; and
- Update background data transfer based on the selection provided by AF.

Npcf_BDTPolicyControl_Create service operation

The Npcf_BDTPolicyControl_Create service operation is used by the NEF (on request from an Application Service Provider) to request a background data transfer policy. The NEF provides an ID of the application service provider, the expected data volume per UE, The number of UE and desired time window. It may also indicate a network area where the UEs are located. The PCF responds with a one or more background data transfer policies and a Background Data Transfer Reference ID. The Reference ID can e.g., be used to request updates of the Background data transfer policy.

Npcf_BDTPolicyControl_Update service operation

The Npcf_BDTPolicyControl_Update service operation is used by the NEF to request updates to the background data transfer policy from the PCF. The NEF provides an identifier for the application service provider, background data transfer policy and the Background Data Transfer Reference ID. The PCF may respond with a new background data transfer policy to the NEF.

13.2.3.5 Npcf_UEPolicyControl service

The Npcf_UEPolicyControl service is used by the AMF to create and manage a UE Policy Association with the PCF through which the AMF Service Consumer receives Policy Control Request Trigger of UE Policy Association. The association allows PCF to provide UE access selection and PDU Session selection related policy information to the UE transparently through the AMF that provides using NAS messages to carry the UE policy container. In case of roaming the AMF use the Npcf_UEPolicyControl Service provided by the PCF in the visited network (V-PCF), the V-PCF will in turn use the Npcf_UEPolicyControl Service provided by the Home PCF (H-PCF).

As part of this service, the PCF may provide the NF Service Consumer, e.g., AMF, with policy information about the UE that may contain:

- UE access selection and PDU Session selection related policy information as defined in clause 6.6 of 3GPP TS 23.503. In the case of roaming, the URSP information is provided by H-PCF and the ANDSP information can be provided by V-PCF or H-PCF or both;
- Policy Control Request Trigger of UE Policy Association. When such a Policy Control Request Trigger condition is met, the NF Service Consumer, e.g., AMF, shall contact PCF and provide information on the Policy Request Trigger condition that has been met. In the case of roaming, the V-PCF may subscribe to AMF or the H-PCF may subscribe to AMF via V-PCF.

At Npcf_UEPolicyControl_Create, the NF Service Consumer, e.g., AMF, requests the creation of a corresponding "UE Policy Association" with the PCF (Npcf_UEPolicyControl_Create) and provides relevant parameters about the UE context to the PCF. When the PCF has created the UE Policy Association, the PCF may provide policy information as defined above.

When a Policy Control Request Trigger condition is met, the NF Service Consumer, e.g., AMF, requests the update (Npcf_UEPolicyControl_Update) of the UE Policy Association by providing information on the condition(s) that have been met. The PCF may provide updated policy information to the NF Service Consumer.

During the AMF relocation, if the target AMF receives the PCF ID from source AMF and the target AMF decides to contact with the PCF identified by the PCF ID based on the local policies, the target AMF requests the update (Npcf_UEPolicyControl_Update) of the UE Policy Association. If a Policy Control Request Trigger condition is met, the information matching the trigger condition may also be provided by the target AMF. The PCF may provide updated policy information to the target AMF.

The PCF may at any time provide updated policy information (Npcf_UEPolicyControl_UpdateNotify).

At UE deregistration the NF Service Consumer, e.g., AMF, requests the deletion of the corresponding UE Policy Association.

Npcf_UEPolicyControl_Create service operation

The Npcf_UEPolicyControl_Create service operation is used by the AMF to request the creation of a UE Policy Association. The AMF provides the SUPI of the UE and may include other parameters e.g., Access Type, Permanent Equipment Identifier, GPSI, User Location Information, UE Time Zone, Serving Network, RAT type, UE access selection and PDU session selection policy information including the list of PSIs, OS id and Internal Group. The PCF provides the Home PCF ID to the AMF and may also provide Policy Control Request Trigger for the UE Policy Association.

The UE Policy Association allows the PCF to send policy information to the UE via the AMF. The Policy Control Request Trigger may be provided to the AMF so that the AMF can inform the AMF when certain events occur, and the PCF may want to provide new policies to the UE. In case of roaming the AMF uses the Npcf_UEPolicyControl_Create Service Operation provided by the V-PCF and the V-PCF will in turn use the Npcf_UEPolicyControl_Create Service Operation provided by the H-PCF.

Npcf_UEPolicyControl_UpdateNotify service operation

The PCF may at any time use the Npcf_UEPolicyControl_UpdateNotify service operation to provide updated Policy information for the UE for an established UE Policy Association. In case of roaming he the H-PCF may invoke the Npcf_UEPolicyControl_UpdateNotify Service Operation towards the V-PCF and the V-PCF can, on its own initiative or because of a notify Service Operation from the H-PCF, invoke the Npcf_UEPolicyControl_UpdateNotify Service Operation towards the AMF.

Npcf_UEPolicyControl_Delete service operation

The Npcf_UEPolicyControl_Delete service operation allows the AMF to delete the UE policy control association in the PCF. In case of roaming AMF uses the Npcf_UEPolicyControl_Delete service operation provided by the V-PCF and the V-PCF will in turn use the Npcf_UEPolicyControl_Delete service operation provided by the H-PCF.

Npcf_UEPolicyControl_Update service operation

The Npcf_UEPolicyControl_Update service operation allows the AMF to request an update of the UE Policy Association to receive updated Policy information for the UE context. When the AMF detects that a Policy Control Request Trigger condition is met, the AMF requests an update by invoking the Npcf_UEPolicyControl_Update service operation of the UE Policy Association and provides information on the condition(s) that have been met. The PCF may provide updated policy information to the AMF.

The Npcf_UEPolicyControl_Update service operation can also be used during an AMF relocation, if the new AMF receives the PCF ID from source AMF and the target AMF decides to contact the PCF identified by the PCF ID, the new AMF invokes the Npcf_UEPolicyControl_Update service operation for the UE Policy Association. The PCF may provide updated policy information to the target AMF.

In case of roaming AMF uses the Npcf_UEPolicyControl_Update service operation provided by the V-PCF and the V-PCF will in turn use the Npcf_UEPolicyControl_Update service operation provided by the H-PCF.

13.2.3.6 Npcf_EventExposure service

The Npcf_EventExposure service allows an NF e.g., the NEF to subscribe, modify and get notified about PCF events for a group of UE(s) or all UEs sharing the same a DNN and S-NSSAI. The Npcf_EventExposure service has three service operations Npcf_EventExposure_Subscribe, Npcf_EventExposure_UnSubscribe, and Npcf_EventExposure_Notify.

The PCF can expose information about events like:

- PLMN identifier notification
- Change of Access Type

Event filter can be used by the requesting NF to narrow down the specific event of interest. Event Filters specify the conditions to meet for triggering notification and can include one or more Parameters and the values that each parameter should match to trigger a notification.

Npcf_EventExposure_Subscribe service operation

The requesting NF e.g., NEF can use the Npcf_EventExposure_Subscribe service operation to subscribe to or modify event reporting for a group of UE(s) or any UE accessing a combination of (DNN, S-NSSAI). The requesting NF also provides the Event IDs and associated Event filters and in addition, a Notification Correlation ID.

When the PCF accepts the subscription, it responds with a Subscription Correlation ID that is used for managing or removing the subscription and possibly an expiry time for the subscription indicating when the PCF will stop further reporting. The PCF may also include a first event report, if available.

If the requesting NF needs to modify a subscription, that it has previously created, it invokes Npcf_EventExposure_Subscribe service operation with the Subscription Correlation ID and provides updated Event Filters with Event ID(s) to the PCF.

Npcf_EventExposure_UnSubscribe service operation

An NF can use the Nsmf_EventExposure_UnSubscribe Service Operation to stop further event reporting for previously subscribed events. The Subscription Correlation ID that was received when subscribing to the event reporting is used as an input to the PCF to identify the specific events to stop reporting for.

Npcf_EventExposure_Notify service operation

When the PCF detects an event corresponding to a subscription, it invokes the Npcf_EventExposure_Notify service operation, for each subscribed NF that matches the event and event filter. The PCF includes information like PCF ID, Notification Correlation Information, Event ID, corresponding UE (SUPI and if available GPSI) and time stamp. The Notification Target Address and Notification Correlation ID helps the Receiving NF identify the event notification subscription. In addition, the PCF also included event specific parameter that indicates the type of event that has occurred and related information.

13.2.4 UDM services

The UDM acts as a service producer for five services Nudm_UEContextManagement, Nudm_SubscriberDataManagement, Nudm_UEAuthentication, Nudm_EventExposure, and Nudm_ParameterProvision as shown in Fig. 13.5. The UDM services are used by the AMF, SMF, SMSF, NEF, GMLC, and AUSF via the Nudm service based interface.

If the UDM is stateless and store information externally in a UDR it makes use of the Nudr services as described in Section 13.2.8.

The Nudm_UEContextManagement service is used for UE context management and allow NFs like the AMF, SMF and SMSF to register and deregister with UDM and can provide the NFs with information related to UE's e.g., a UE's serving NF

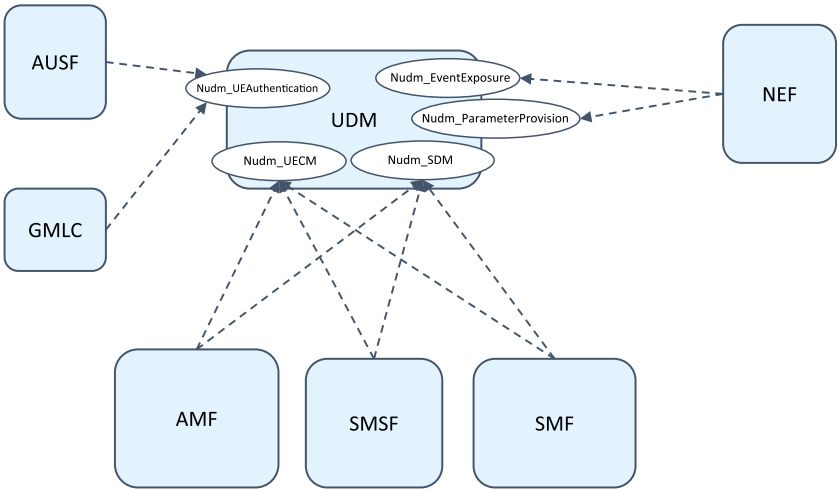

Fig. 13.5 UDM services.

identifier, UE status, etc. The Nudm_UEContextManagement Service is also known by a shorter version of the name, Nudm_UECM.

The Nudm_SubscriberDataManagement service is used to manage subscription data and enables NFs like AMF and SMF to retrieve user subscription data and allows the UDM to provided updates of subscriber data. The Nudm_SubscriberDataManagement Service is also known as the Nudm_SDM service.

The Nudm_UEAuthentication service provides authentication subscriber data to the e.g., AMF. For AKA based authentication, this operation can be also used to recover from security context synchronization failure situations. Used for being informed about the result of an authentication procedure with a UE.

The Namf_EventExposure service allows NFs to subscribe to events and can provides monitoring indication of the events to the subscribed NF consumer.

The Nudm_ParameterProvision service is used to provision information which can be used for the UE in 5GS.

13.2.4.1 Nudm_UECM (Nudm_UEContextManagement) service

The Nudm_UEContextManagement service is used by NFs (AMF, SMF, SMSF) to manage the registration of the serving NFs with UDM and to retrieve registration information e.g., to route terminating requests to the right serving NF.

The following service operations are defined for the Nudm_UEContextManagement service:

- Registration
- DeregistrationNotification

- Deregistration
- Get
- Update
- P-CSCF-RestorationNotification

Nudm_UECM_Registration service operation

The Nudm_UECM_Registration service operation is used by NFs (AMF, SMF, SMSF) to register at the UDM as the NF serving the UE (AMF and SMSF) or the NF serving a PDU session (SMF).

The AMF uses the Nudm_UECM_Registration to register as the serving NF for a UEs access and mobility management service during registration and in the same way the SMSF registers as the NF serving the UE for SMS. The SMF uses the Nudm_UECM_Registration register as the serving NF for session management services during PDU Session establishment.

The NF invoking the Nudm_UECM_Registration Service Operation provides it's NF ID, NF Type the SUPI of the UE. The UDM authorizes the request and if accepted the NF is set as the UE serving the UE.

When it's an AMF that uses the Nudm_UECM_Registration Service Operation, it is implicitly subscribed to be notified of deregistration's in UDM e.g., in case a UE moves to a different AMF. The notification are sent by UDM to a previously registered AMF with the Nudm_UECM_DeregistrationNotification service operation.

Nudm_UECM_DeregistrationNotification service operation

The Nudm_UECM_DeregistrationNotification service operation is used by UDM to notify an AMF that it has been deregistered as the serving NF for a UE e.g., due to mobility to a different AMF. The UDM provides the UEs SUPI and a deregistration reason e.g.:

- UE Initial Registration.
- UE Registration area change.
- Subscription Withdrawn.
- 5GS to EPS Mobility.

Nudm_UECM_Deregistration service operation

The Nudm_UECM_Deregistration service operation is used by the a previously registered NF (AMF, SMF or SMSF) to deregister from the UDM. The UDM receiving the request deletes the information related to the NF in the UE context and responds to the NF with an indication in the deregistration was successful or not.

When it's an AMF invoking the Nudm_UECM_Deregistration Service Operation it also means that the subscriptions to be notified when the NF is deregistered in UDM (i.e., Nudm_UECM_DeregistrationNotification) is also removed.

Nudm_UECM_Get service operation

The Nudm_UECM_Get Service Operation is used by NFs (e.g., NEF, GMLC, SMSF) to retrieve registration information from the UDM e.g., the NF ID where the UEs access and mobility management context or the PDU Sessions context can be reached. The requesting NF provides a UE ID the NF Type it's interested in. The Nudm_UECM_Get Service Operation uses the UE ID and NF type to search for the registered NF which is returned to the requestor.

SUPI, NF ID or SMS address of the NF corresponding to the NF type requested by NF consumer.

Nudm_UECM_Update service operation

The Nudm_UECM_Update service operation can be used by a registered NF (AMF or SMF) to update the stored registration information (e.g., UE capabilities, PGW-C + SMF FQDN for S5/S8 interface, etc.).

The consumer NF provides it's NF ID and type, the SUPI of the UE, a reference to the UE context information and the modification instruction.

Nudm_UECM_PCscfRestoration service operation

The Nudm_UECM_PCscfRestoration service operation is used to notify registered NFs (AMF, SMF) when UDM detects the need for P-CSCF restoration.

UDM notifies the AMF and/or SMF(s) that, during registration in UDM, indicated the need to be notified of P-CSCF Restoration.

13.2.4.2 Nudm_SubscriberDataManagement (SDM) service

The Nudm_SubscriberDataManagement service, also called Nudm_SDM Service, is used by NFs to retrieve subscription data from the UDM. The subscription data is structured into different data types and NFs retrieve the set of data types that they need for their operation. A key is used to identify the corresponding Subscription Data Type data.

Table 13.1 Lists the subscription data types, the main key and a non exhaustive list of the actual subscription data.

Nudm_SDM_Get service operation

The Nudm_SDM_Get Service operation is used by consumer NF to retrieve subscriber data. The Consumer NF indicates the subscription data types and corresponding keys and the UDM checks that the requesting NF is authorized to retrieve the requested subscription data. If the authorizations is successful the UDM responds with the requested data types.

Table 13.1 Subscription data types

Subscription data types	Data key	Example data
Access and Mobility Subscription data	SUPI	GPSI List, Group ID-list, Default S-NSSAIs, UE Usage Type, RAT restriction, Forbidden area, Service Area Restriction, Core Network type restriction, RFSP Index, UE behavioral information/Communication patterns, Subscribed DNN list, etc.
SMF Selection Subscription data	SUPI	S-NSSAI, Subscribed DNN list, Default DNN, LBO Roaming Information, Interworking with EPS indication list
UE context in SMF data	SUPI	PDU Session Id(s), DNN, SMF ID and address, PGW-C + SMF FQDN
SMS Management Subscription data	SUPI	SMS subscription, SMS barring list etc.
SMS Subscription data	SUPI	Indicates subscription to any SMS delivery service over NAS
UE Context in SMSF data	SUPI	AMF, Access Type, etc.
Session Management Subscription data	SUPI	GPSI List, Internal Group ID-list, S-NSSAI, Subscribed DNN list, DNN, UE Address, Allowed PDU Session Types, Default PDU Session Type, Allowed SSC modes, Default SSC mode, 5GS Subscribed QoS profile etc.
Identifier translation	GPSI	SUPI and optionally MSISDN
Slice Selection Subscription data	SUPI	Subscribed S-NSSAIs
Intersystem continuity Context	SUPI	List of (DNN + PGW FQDN)

Nudm_SDM_Notification service operation

The Nudm_SDM_Notification service operation is used by the UDM to notify NFs consumer of updates of previously retrieved subscriber data. The UDM includes the updated Subscription Data Type corresponding keys.

The UDM invokes the Nudm_SDM_Notification service operation when the subscriber data is updated at the UDM or when the UDM needs to deliver e.g., Steering of Roaming information, a new Routing Indicator or a new Default Configured NSSAI to a UE.

Nudm_SDM_Subscribe service operation

The Nudm_SDM_Subscribe service operation is used by NFs (AMF, SMF, and SMSF) to subscribe to updates of UE subscriber data. The AMF and SMSF subscribes to be notified of updates after successfully retrieving subscription data, with the Nudm_SDM_Get

service operation, during the registration procedure. Similarly, the SMF subscribes to be notified of updates after successfully retrieving subscription data, with the Nudm_SDM_Get service operation, during a PDU session establishment. The subscribing NF includes subscription data type(s) and corresponding key(s).

Nudm_SDM_Unsubscribe service operation

The Nudm_SDM_Unsubscribe service operation is used by NFs e.g., AMF and SMF to unsubscribe to further notifications of updates to UE's subscriber data.

Nudm_SDM_Info service operation

The Nudm_SDM_Info service operation is used by the AMF to provide UDM with status information regarding subscription data management procedures towards the UE. It is e.g., used to provide UE acknowledgment of Steering of Roaming information from and UE acknowledgement of successful Network Slicing Configuration after delivery of the Network Slicing Subscription Change Indication via the AMF.

13.2.4.3 Nudm_UEAuthentication service

This service is used by the AUSF to get authentication data and provide UDM with the result of the authentication procedure success. If the concealed identity, SUCI, is used as an input the UDM will also provide the corresponding SUPI to the AUSF.

Nudm_UEAuthentication_Get service operation

The Nudm_UEAuthentication_Get service operation is used by the AUSF to retrieve authentication data from UDM. The UDM indicates the authentication method to use and the corresponding authentication data for a certain UE as identified by SUPI or SUCI. If SUCI is used, the UDM also returns the SUPI.

UEAuthentication_ResultConfirmation service operation

The UEAuthentication_ResultConfirmation service operation is used by the AUSF to inform UDM about of the result of an authentication procedure with a UE.

The AUSF provides the SUPI, a timestamp of the authentication, the authentication method and the serving network name to the UDM.

13.2.4.4 Nudm_EventExposure service

The Nudm_EventExposure service allows the NEF to subscribe, unsubscribe and get notified about events from the UDM. UDM can support events like e.g., UE reachability for SMS, change of PEI (i.e., the UE HW or SW has been changed) and roaming status.

Nudm_EventExposure_Subscribe service operation

The Nudm_EventExposure_Subscribe service operation allows the NEF to subscribe to or update event subscriptions. The NEF provides the target of the subscribe service operation: UE ID(s) (SUPI, GPSI, Internal Group Identifier or External Group Identifier, or indication that all UEs are targeted). The NEF also includes Event filters with Event Id(s) and Event Reporting Information.

When the subscription is accepted by the UDM it provides a Subscription Correlation ID and possibly an Expiry time. The UDM may also include an event report, if information is available.

Nudm_EventExposure_Unsubscribe service operation

The Nudm_EventExposure_Unsubscribe service operation allows the NEF to delete the subscription to event in UDM that it previously subscribed to. The NEF includes the Subscription Correlation ID, received in the Nudm_EventExposure_Subscribe Service Operation, to enable the UDM to identify the subscription to delete.

Nudm_EventExposure_Notify service operation

The Nudm_EventExposure_Notify service operation is used by UDM to report on events that was previously subscribed by the NEF. The UDM provides Event ID, Notification Correlation Information, time stamp and any event specific parameters.

13.2.4.5 Nudm_ParameterProvision service

The Nudm_ParameterProvision service allows the NEF (or rather AF via the NEF) to provision of information which can be used for the UE in 5GS.

Nudm_ParameterProvision_Update service operation

The Nudm_ParameterProvision_Update service operation allows provisioning of some parameters in the UDM e.g., Expected UE Behaviour, Network Configuration parameters. The NEF provides the GPSI, AF ID, Transaction Reference ID(s) and the parameters to provision e.g., Expected UE Behaviour parameters or at least one of the Network Configuration parameters and a Validity Time.

When accepted the UDM updates the respective subscription data types and updates any NF that has subscribed to updates of those subscription data types.

13.2.5 NRF services

The NRF and its services are key enablers in a service based architecture. The NRF centralizes and automates the configuration required for NF/NF services to discover, select and connect to peer NF/NF services with the correct capabilities. To do this the NRF provides three services Nnrf_NFManagement, Nnrf_NFDiscovery, and Nnrf_AccessToken. The Nnrf_NFManagement enables NFs to register and manage their NF

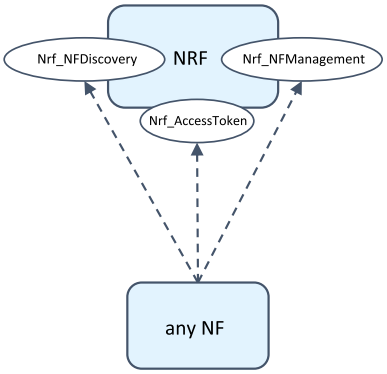

Fig. 13.6 NRF services.

services and capabilities in the NRF as shown in Fig. 13.6. The Nnrf_NFDiscovery allows NFs/NF Services to discover NFs/NF Services that match provided criteria. The Nnrf_AccessToken allows the NFs to request Auth2.0 access tokens that can be used to access services from other NFs.

13.2.5.1 Nnrf_NFManagement service

The Nnrf_NFManagement service has a set of service operations that allows NFs to register, update, deregister their NF profile including all NF Services in the NRF. It also has service operations that allows other NFs to subscribe to notifications of new, updated and removed NFs in the network. Note that as an alternative to the NF using the service Nnrf_NFManagement itself, another function e.g., OAM may use the service on behalf of the NF.

Nnrf_NFManagement_NFRegister service operation

The Nnrf_NFManagement_NFRegister service operation registers the NF and its NF services in the NRF by providing the NF profile of the consumer NF to NRF. All NF profiles contains information like: NF type, NF instance ID, NF service Names, PLMN ID and addressing information. In addition the NF profile contains information that is useful for discovery and selection and this information varies somewhat from NF to NF.

As result of a successful registration of the profile with the Nnrf_NFManagement_NFRegister service operation the NRF also marks the NF as available and will notify any NFs that has subscribed to this information.

Nnrf_NFManagement_NFUpdate service operation

The Nnrf_NFManagement_NFUpdate service operation allows NFs to update the NF profile in the NRF. The NF may replace the full NF profile, or it can update parts of the

NF profile by providing only the NF profile elements that needs to be updated and their new values.

As result of a successful update of the profile with Nnrf_NFManagement_NFUpdate the service operation the NRF also notifies any NFs that has subscribed to this information.

Nnrf_NFManagement_NFDeregister service operation

The Nnrf_NFManagement_NFDeregister service operation allows NFs to inform the NRF that they will no longer be available. The NRF marks the NF as unavailable, it may remove the profile information and inform any NF that has subscribed to information about the status of the NF.

Nnrf_NFManagement_NFStatusSubscribe service operation

The Nnrf_NFManagement_NFStatusSubscribe service operation allows NFs to subscribe to be notified if a new registered NF registers, updates its profile or deregisters. The NF can subscribe to information regarding:

- NF type, if NF status of a specific NF type is to be monitored
- NF instance ID, if NF status of a specific NF instance is to be monitored
- NF service, if NF status for NF which exposes a given NF service is to be monitored

In addition, the NF may further narrow down the subscription by providing additional parameters to match e.g., S-NSSAI(s) and the associated NSI ID(s), GUAMI(s) for AMF etc.

When the NRF accepts the subscription, it responds with a Subscription Correlation ID that is used for management of the subscription.

Nnrf_NFManagement_NFStatusNotify service operation

The Nnrf_NFManagement_NFStatusNotify service operation enables the NRF to notify subscribed NFs of newly registered NF along with its NF services, Updated NF profiles and Deregistered NF.

The NRF provides NF instance ID, NF Status and:

- The NF services (if the notification is for newly registered NF)
- The new NF profile (if the notification is for updated NF profile)
- Indication that an NF has deregistered.

Depending on the NF there may be additional parameters provided e.g., S-NSSAI(s) and the associated NSI ID(s), location of the NF, For AMF, list of GUAMI(s), TAI(s).

Nnrf_NFManagement_NFStatusUnsubscribe service operation

The Nnrf_NFManagement_NFStatusUnsubscribe service operation allows NF Consumers to unsubscribe from further notifications. The NF provides the Subscription Correlation ID to the NRF. The NRF uses the Subscription Correlation ID to identify the subscription deletes the associated resources.

13.2.5.2 Nnrf_NFDiscovery service

The Nnrf_NFDiscovery service is used to discovery of candidate NF instances with specific NF service or a target NF type. It also enables one NF service to discover a specific NF service. Based on the discovery result the NF can select a target NF/NF Service and initiate communication.

Nnrf_NFDiscovery_Request service operation

The Nnrf_NFDiscovery_Request service operation provides the requesting NF/NF Service a set of NF instances and its NF Services and additional information from the NF profile.

The NF service consumer provides one or more target NF service Name(s), NF type of the target NF, NF type of the NF requestor. If the NF service consumer intends to discover an NF service producer providing all the standardized services, it provides a wildcard NF service name. Depending on the NF and NF service the consumer wish to discover it may provide additional information like:

- S-NSSAI and the associated NSI ID
- DNN
- Target NF/NF service PLMN ID
- Serving PLMN ID
- NF service consumer ID
- NF location
- TAI
- The UE's Routing Indicator
- AMF region, AMF Set, GUAMI (for AMF)
- Group ID of the NF to discover

The NRF will search its internal database and match the input parameters and respond with a set of suitable NF instances, containing per NF Instance:

- NF Type
- NF Instance ID
- FQDN or IP address(es) of the NF instance
- List of NF Services Instances, each with:
  - Service Name
  - NF service instance ID
  - Optionally Endpoint Address(es) (list of IP addresses or an FQDN)

In addition, the NRF may, depending on the NF instance type, provide additional information from the NF profile, e.g.:

- If the target NF is BSF: Range(s) of (UE) IPv4 addresses or Range(s) of (UE) IPv6 prefixes.
- If the target NF stores Data Set(s) (e.g., UDR): Range(s) of SUPIs, range(s) of GPSIs, range(s) of external group identifiers, Data Set Identifier(s).

- If the target NF is UDM, UDR or AUSF, they can include UDM Group ID, UDR Group ID, AUSF Group ID.
- For UDM and AUSF, Routing Indicator.
- If the target NF is AMF, it includes list of GUAMI(s).
- If the target NF is CHF, it includes primary CHF instance and the secondary CHF instance pair(s).
- S-NSSAI(s) and the associated NSI ID(s).
- Location of the target NF.
- TAI(s).
- PLMN ID.

The NF Consumer uses the received set of suitable NFs to select a specific NF instance and NF service instance to initiate communication with. The NF consumer may also cash the discovered set of suitable NF instances. The cashed information may be reused for subsequent discovery requests that match the same criteria.

13.2.5.3 Nnrf_AccessToken service

The Nnrf_AccessToken service provides OAuth2 Access Tokens for NF to NF authorization for more information on OAuth2 authorization, see Chapter 8.

Nnrf_AccessToken_Get service operation

The Nnrf_AccessToken_Get Service Operation allows an NF consumer to request an NRF to authorize the consumer and provide an Access Token. The NF consumer can subsequently use the access token to show an NF Service Producer that it is authorized to use the service.

In the request the NF consumer provides NF Instance Id of the NF service consumer, NF producer service name(s), NF types of the NF producer instance and NF consumer. For roaming cases the home and visited PLMN IDs are also provided.

If authorization is successful the NRF provides an Access Token with appropriate claims, where the claims shall include NF Instance Id of NRF (issuer), NF Instance Id of the NF Service consumer (subject), NF type of the producers (audience), expected service name (scope) and expiration time (expiration).

13.2.6 AUSF services

The AUSF provides NF Service Consumers the following services:

- Nausf_UEAuthentication, authenticate the UE and provide keying material (AMF)
- Nausf_SoRProtection, protects the Steering Information List for the requester NF (UDM)
- Nausf_UPUProtection (UDM)

As shown in Fig. 13.7 the AMF and UDM are the NFs using the AUSF.

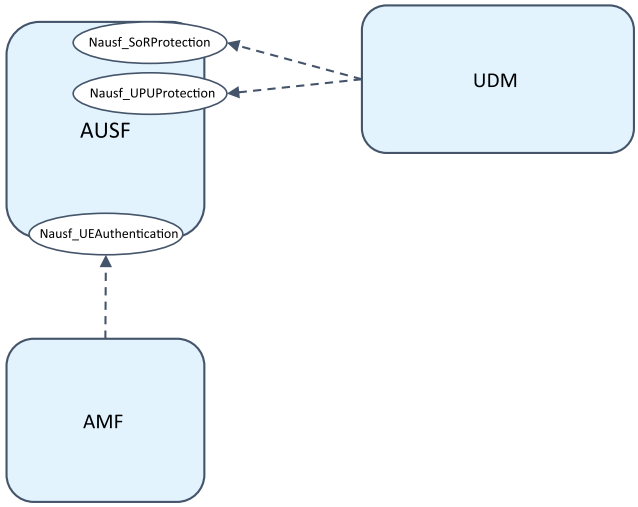

Fig. 13.7 AUSF services.

13.2.6.1 Nausf_UEAuthentication service

The Nausf_UEAuthentication service authenticates the UE and provides related keying material. It is used by the AMF and it has single service operation: Nausf_UEAuthentication.

Nausf_UEAuthentication service operation

The Nausf_UEAuthentication service operation is used by the AMF to initiate Authentication of the UE by providing the following information:

- UE id (SUPI or SUCI)
- Serving Network Name

Depending on the selected authentication method the AUSF executes either 5G-AKA or EAP-based authentication procedure. The initial requests create a resource. The content of the resource will depend on the procedure and will be returned to the AMF. The resources is used for subsequent requests carrying information as per the procedure executed for more information, see Chapter 8.

After executing the selected authentication procedure (several request/responses carrying the procedure messages) the AUSF will respond to the AMF with the authentication result and if success the master key which are used by AMF to derive NAS security keys and other security key(s). The AUSF will also provide the SUPI if the authentication was initiated with SUCI.

13.2.6.2 Nausf_SoRProtection service

The Nausf_SoRProtection service allows the UDM to request AUSF to provide protection parameters for the Steering of Roaming information (SoR). This prevents the

VPLMN to tamper with or remove the SoR information. This service also allows the AUSF to provide the UDM with information to verify that the UE received the Steering Information List.

Nausf_SoRProtection service operation

The Nausf_SoRProtection Service Operation is used by the UDM to protect SoR information. The UDM provides it's ID, SUPI of the UE and a SoR Header and optionally an ACK indication in the Request. The AUSF derives the SoR protection and returns it in the response to the UDM. If the ACK indication is included in request the AUSF also derives and returns information to validate the UE response in the SoR procedure. The UDM uses the received protection key to protect the SoR information in SoR procedures.

13.2.6.3 Nausf_UPUProtection service

The Nausf_UPUProtection service allows the UDM to request AUSF to provide protection parameters for the UE Parameters Update procedure.

Nausf_UPUProtection service operation

The Nausf_UPUProtection Service Operation provides security parameters to UDM for UE parameter updates. This operation provides the UDM with security parameters to protect the UE Parameters Update Data from being tampered with or removed by the VPLMN.

13.2.7 SMSF services

The SMSF provides the Nsmsf_SMService, as shown in Fig. 13.8 that allows activating and deactivating SM Service and to send uplink SMS messages.

13.2.7.1 Nsmsf_SMService service

The Nsmsf_SMService service allows the AMF to request the SMSF to activate and deactivate SM Service and to send uplink SMS messages.

Nsmsf_SMService_Activate service operation

The Nsmsf_SMService_Activate service operation is used by the AMF in the registration procedure to activate and authorize SM services. The AMF provides it's NF ID, the

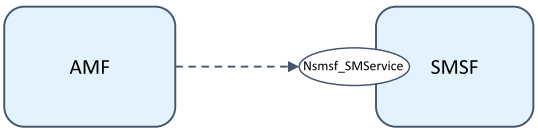

Fig. 13.8 SMSF services.

SUPI and additional information in the request. The SMSF will register in the UDM and download subscription data and it will provide a successful response to the AMF if the UE is authorized to use SMS.

Nsmsf_SMService_Deactivate service operation

The Nsmsf_SMService_Deactivate service operation removes SMS service authorization from SMSF for a given SUPI. The Service operation is used by the AMF that includes a SUPI in the request. The SMSF deregisters with UDM and may delete data and resources related to the SUPI. The SMSF also responds with a deactivation result to the AMF.

Nsmsf_SMService_UplinkSMS service operation

The Nsmsf_SMService_UplinkSMS service operation is used by the AMF to pass uplink SMS messages from the UE to the SMSF. As a prerequisite the AMF and SMSF must have activated and authorized the SM Service. The AMF includes the SUPI and the SMS payload received from the UE in the request towards the SMSF. The SMSF sends the SM towards the SMS Service Centre and responds to the AMF with a transmission result.

13.2.8 UDR services

The Nudr_DataManagement (also called Nudr_DM) service, shown in Fig. 13.9, allows NF consumers to query, create, update, subscribe for change notifications, unsubscribe for change notifications and delete data stored in the UDR, based on the set of data applicable to the consumer.

Initially Data Sets and Data Set Identifiers have been specified for: Subscription Data, Policy Data, Application data and Data for Exposure. The Data Sets and Data Set Identifiers are intended to be extensible to cater for additional new identifiers as well as for operator specific identifiers and related data.

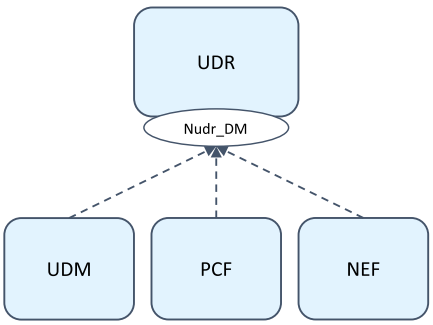

Fig. 13.9 UDR services.

13.2.8.1 Nudr_DataManagement (DM) service

The Nudr_DM service has the following service operations:

- Query
- Create
- Delete
- Update
- Subscribe
- Unsubscribe
- Notify

Common for all operation are that they can use the following parameters to specify the data they want to operate on:

- Data Set Identifier: Uniquely identifies the requested set of data within the UDR.
- Data Subset Identifier: It uniquely identifies the data subset within each Data Set Identifier.
- Data Keys (e.g., SUPI, GPSI, etc.).

For Nudr_DM_Subscribe and Nudr_DM_Notify operations:

- The Target of event reporting is made up of a Data Key and possibly a Data Sub Key
- The Data Set Identifier plus (if present) the (set of) Data Subset Identifier(s) corresponds to a (set of) Event ID(s).

An NF Service Consumer may include an indicator when it invokes Nudr_DM Query/Create/Update service operation to subscribe the changes of the data, to avoid a separate Nudr_DM_Subscribe service operation.

Nudr_DM_Query service operation

The Nudr_DM_Query service operation allows the NF service consumer (e.g., UDM) to requests a set of data from UDR. The NF Service Consumer provides Data Set Identifier and optionally Data Key(s), Data Subset Identifier(s), Data Sub Key(s). SUPI may also be included to identify which UE the latest list of stored PSIs belongs to. The UDM responds with the requested data.

Nudr_DM_Create service operation

The Nudr_DM_Create service Operation is used by NF service consumer to insert a new data record into the UDR, e.g., the NEF inserting a new application data record into the UDR. The requesting NF provides the Data Set Identifier, Data Key(s), optionally Data Subset Identifier(s), Data Sub Key(s) and the data. The UDR stores the data and responds with a result code.

Nudr_DM_Delete service operation

The Nudr_DM_Delete Service operation allows the NF service consumer to delete data stored in the UDR, e.g., a NEF service consumer want to delete an application data

record. The requesting NF provides the Data Set Identifier, Data Key(s), optionally Data Subset Identifier(s), Data Sub Key(s) and the data. The UDR deletes the the data and responds with a result code.

Nudr_DM_Update service operation

The Nudr_DM_Update service operation allows the consumer to update that is stored data in the UDR. The requesting NF (e.g., UDM) provides the Data Set Identifier, Data Key(s), optionally Data Subset Identifier(s), Data Sub Key(s) and the data. The UDR updates the specified data and responds with a result code.

Nudr_DM_Subscribe service operation

The Nudr_DM_Subscribe Service operation enables the NF service consumer (e.g., UDM) to subscription to notification of data modified in the UDR. The events can be changes on existing data or addition of data. The requesting NF provides a Data Set Identifier, Notification Target Address, Notification Correlation ID and Event Reporting Information. In case of modification of an existing subscription the requesting NF also includes the previously received Subscription Correlation ID. The UDR accepts the subscription and responds with a Subscription Correlation ID.

Nudr_DM_Unsubscribe service operation

The Nudr_DM_Unsubscribe service operation allow the NF service consumer to remove previous subscriptions. The requesting NF provides the Subscription Correlation ID that allows the UDR to identify and remove the subscription information.

Nudr_DM_Notify service operation

The Nudr_DM_Notify service operation allows the UDR to notify previously subscribed notification targets about modification of data, when data in the UDR is added, modified or deleted. The UDR uses the Notification Target Address in the subscription and includes Notification Correlation Information, Data Set Identifier and the Updated Data.

13.2.9 5G-EIR services

The 5G-EIR provides a N5g-eir_EquipmentIdentityCheck service, as shown in Fig. 13.10, that is used by the AMF to check whether the Permanent Equipment ID (PEI) is on the black list or not. The N5g-eir_EquipmentIdentityCheck has a single service operation.

13.2.9.1 N5g-eir_EquipmentIdentityCheck_Get service operation

The N5g-eir_EquipmentIdentityCheck_Get service operation allows the AMF to check the PEI and determine whether the subscriber is allowed to use the equipment or not.

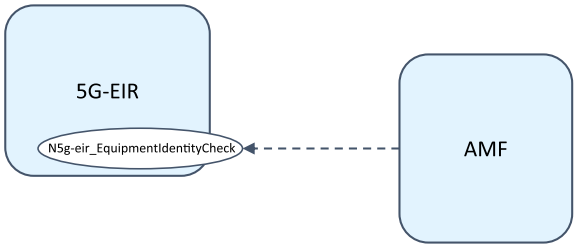

Fig. 13.10 5G-EIR services.

The AMF receives the PEI during the registration procedure and may use the N5g-eir_EquipmentIdentityCheck_Get Service operation offered by the 5G-EIR. The AMF provides the PEI and SUPI in the request. The 5G-EIR checks the PEI and responds to the AMF that indicates if the PEI is white-, gray- or black-listed. Based on the result the AMF determines if it can continue the registration procedure or reject the UE.

13.2.10 NWDAF services

The following NWDAF provides two services Nnwdaf_EventsSubscription and Nnwdaf_AnalyticsInfo, as shown in Fig. 13.11. The Nnwdaf_EventsSubscription service enables the NF service consumers to subscribe/unsubscribe for different type of information from NWDAF. The Nnwdaf_AnalyticsInfo service enables the NF service consumers to request different types information from NWDAF.

In 3GPP Release 15, the NDWAF is limited to load level event in one or more Network Slice Instances and possibly Load Level Thresholds. In later releases it is expected that the NWDAF will support additional events and event filters.

13.2.10.1 Nnwdaf_EventsSubscription service

The Nnwdaf_EventsSubscription service enables the consumer to subscribe/unsubscribe to notification of load-based events in Network Slice instances. Periodic notification and notification upon threshold exceeded can be subscribed.

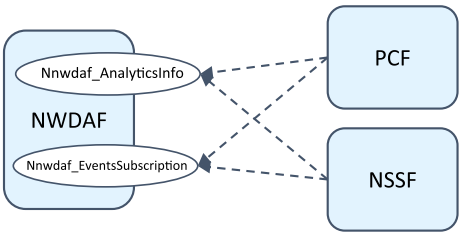

Fig. 13.11 NWDAF services.

Nnwdaf_EventsSubscription_Subscribe service operation

The Nnwdaf_EventsSubscription_Subscribe service operation allows e.g., the NSSF to subscribe to NWDAF events. The requesting NF provides S-NSSAI, Event ID(s), Notification Target Address, Notification Correlation ID and Event Reporting Information. Event Filter(s) e.g., Load Level Threshold value may also be included. In case of modification of an existing subscription the requesting NF also includes the previously received Subscription Correlation ID. The NWDAF accepts the subscription and responds with a Subscription Correlation ID.

Nnwdaf_EventsSubscription_Unsubscribe service operation

The Nnwdaf_EventsSubscription_Unsubscribe service operation allow the NF service consumer to remove previous subscriptions. The requesting NF provides the Subscription Correlation ID that allows the NWDAF to identify and remove the subscription information.

Nnwdaf_EventsSubscription_Notify service operation

The NWDAF notifies the notification target that an subscribed event has occurred. Depending upon type of subscription this notification is either on a periodic basis or triggered whenever a threshold (as defined in the subscribe operation) is crossed. The NWDAF uses the Notification Target Address and includes the Event ID, Notification Correlation ID, S-NSSAI and the Load level information for the Network Slice instance.

13.2.10.2 Nnwdaf_Analytics_Info service

The Nnwdaf_Analytics_Info service enables the consumer to request and get from NWDAF load level information of Network Slice instance(s). This service has a single Service operation.

Nnwdaf_AnalyticsInfo_Request service operation

The Nnwdaf_AnalyticsInfo_Request service operation allows NF consumers to request load information for one of more network slices. The requesting NF specifies Event ID: load level information and can include one or more network slice instance(s) in the event filter. The NWDAF responds with the requested load information for the specified network slice instances.

13.2.11 UDSF services

The UDSF services was only defined on a stage 2 level in 3GPP Release 15. There was no stage 3 protocol solution defined but it is expected that later releases will study suitable protocol solutions that can support the performance requirements on dynamic data access required by NFs using the UDSF.

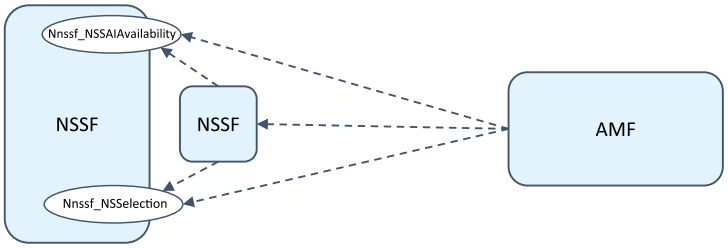

Fig. 13.12 NSSF services.

13.2.12 NSSF services

The NSSF produces two services Nnssf_NSSelection and Nnssf_NSSAIAvailability, as shown in Fig. 13.12. The Nnssf_NSSelection service provides the Network Slice information to the Requester and the Nnssf_NSSAIAvailability service provides the availability of S-NSSAIs on a per TA basis.

13.2.12.1 Nnssf_NSSelection service

The Nnssf_NSSelection service has a single service operation, Nnssf_NSSelection_Get.

Nnssf_NSSelection_Get service operation

The Nnssf_NSSelection_Get Service Operation allows the AMF to request allowed NSSAI and the Configured NSSAI for the Serving PLMN. The AMF may invoke the Nnssf_NSSelection_Get Service Operation during Registration procedure, during PDU Session Establishment procedure or during UE Configuration Update procedure. When invoked during Registration procedure it may possibly trigger AMF re-allocation. The request may in roaming cases the "relayed" from the NSSF in one PLMN to an NSSF in a different PLMN.

If this service operation is invoked during registration AMF provides the Subscribed S-NSSAI(s), default S-NSSAI, Home PLMN ID, TAI, NF type of the NF service consumer, Requester ID. If available requested NSSAI, Mapping of Requested NSSAI, Default Configured NSSAI Indication, Allowed NSSAI for current Access Type, Allowed NSSAI for the other Access Type, and the corresponding Mapping Of Allowed NSSAIs for current Access Type and other Access Type may be provided.

In other cases, the available and relevant information is provided in the request.

The NSSF uses the input information to determine suitable network slice information and provides a response that in the registration case may contains one or more of Allowed NSSAI, Configured NSSAI; Target AMF Set or, based on configuration, the list of candidate AMF(s).

The AMF stores the received information and will use different pieces information in internal functionality, in communication with the UE, RAN and at selection of SMF.

During Registration the AMF will e.g., determine if the it will trigger re-location, during PDU Session establishment.

13.2.12.2 Nnssf_NSSAIAvailability service

The Nnssf_NSSAIAvailability service has two service operations and it enables AMFs to update the NSSF and other AMFs on the availability of S-NSSAIs on a per TA basis.

Nnssf_NSSAIAvailability_Update service operation

The Nnssf_NSSAIAvailability_Update service operation enables the AMF to update the NSSF with the S-NSSAIs the AMF supports per TA. The AMF provides the supported S-NSSAIs per TAI, in the request towards the NSSF. The NSSF responds to the requesting AMF with a list of S-NSSAIs restricted per TAI (if any).

Nnssf_NSSAIAvailability_Notify service operation

The Nnssf_NSSAIAvailability_Notify service operation allows the NSSF to update the AMFs with any S-NSSAIs restricted per TAI and, subsequently remove any restriction per TAI. The NSSF provides a list of TAIs and the S-NSSAIs for which the status is changed (restricted/unrestricted) for each TAI to AMF. The AMF stores the updated information.

13.2.13 LMF services

The following LMF support one service, Nlmf_Location, as shown in Fig. 13.13. The Nlmf_Location service enables the AMF to request location determination for a target UE. It allows the AMF to request the current geodetic and optionally civic location of a target UE. The Nlmf_Location service has one service operation Nlmf_Location_DetermineLocation service operation.

13.2.13.1 Nlmf_Location_DetermineLocation service operation

The Nlmf_Location_DetermineLocation service operation Provides UE location information to the consumer NF. The AMF provides External Client Type and a LCS Correlation Identifier is may also include serving cell identifier, Location QoS, Supported GAD shapes and AMF identity.

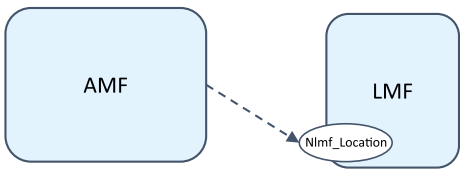

Fig. 13.13 LMF services.

The LMF may execute location procedures (e.g., by invoking other services). The result is provided by the LMF to the AMF and can include Geodetic Location, Civic Location, Position Methods Used.

13.2.14 NEF services

The NEF supports eight services as illustrated in Fig. 13.14 and listed below:

- Nnef_EventExposure, provides support for event exposure
- Nnef_PFDManagement, provides support for PFDs management
- Nnef_ParameterProvision, provides support to provision information which can be used for the UE in 5GS
- Nnef_Trigger, provides support for device triggering
- Nnef_BDTPNegotiation, provides support for negotiation about the transfer policies for the future background data transfer
- Nnef_TrafficInfluence, provide the ability to influence traffic routing
- Nnef_ChargeableParty, requests to become the chargeable party for a data session for a UE
- Nnef_AFsessionWithQoS, requests the network to provide a specific QoS for an AS session

13.2.14.1 Nnef_EventExposure service

Nnef_EventExposure_Subscribe service operation

The Nnef_EventExposure_Subscribe service operation allows internal or external AFs to subscribe to events. The service operation can also be used to update a previous subscription. The requesting AF provides a (Set of) Event ID(s), target of event reporting (GPSI or External Group Identifier), Event Reporting Information Notification Target Address and Notification Correlation ID. The requesting AF may also provide Event Filters to narrow down the event reporting. If the AF want to update a subscription it also includes

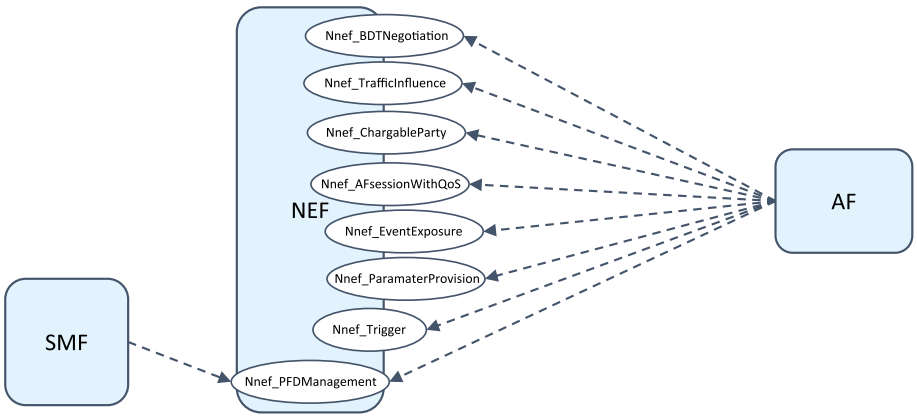

Fig. 13.14 NEF services.

the Subscription Correlation ID that it received when previously subscribing. The NEF does not produce event by itself, but it can in turn subscribe to relevant events from other NFs. The NEF accepts the subscription and responds with a Subscription Correlation ID and possibly an expiry time. The response may also include a first event report if data is available.

Nnef_EventExposure_Unsubscribe service operation

The Nnef_EventExposure_Unsubscribe service operation allows an AF to remove a previously subscription to Event Exposure. The AF invoking the Nnef_EventExposure_Unsubscribe Service operation provides the Subscription Correlation ID. The NEF uses the Subscription Correlation ID to identify and remove the subscription. It acknowledges the removal back to the AF and may delete any related resources.

Nnef_EventExposure_Notify service operation

The Nnef_EventExposure_Notify Service operation allows the NEF to report the event to the consumer that has previously subscribed. The NEF used the Notification Target Address and includes Event ID, Notification Correlation Information, time stamp. The NEF may also include event information (depends on the specific Event).

13.2.14.2 Nnef_PFDManagement service

The Nnef_PFDManagement service provides AF the capability to create, update or remove PFDs via the NEF and for the SMF to fetch or subscribe to PFDs.

Nnef_PFDManagement_Fetch service operation

The Nnef_PFDManagement_Fetch service operation allows the SMF to fetch PFDs for one or more application identifier. The SMF provide the Application Identifier(s). The NEF responds with the Application Identifier(s) and the corresponding PFDs.

Nnef_PFDManagement_Subscribe service operation

The Nnef_PFDManagement_Subscribe service operation allows the SMF consumers to explicitly subscribe the notification of changes of PFDs for Application Identifier(s). The SMF provides Application Identifier(s). The NEF creates a subscription resource which is included in the response to the SMF.

Nnef_PFDManagement_Notify service operation

The Nnef_PFDManagement_Notify service operation is used by the NEF to inform subscribed SMFs of changes to PFDs related to the subscribed Application Identifiers. The NEF included Provides Update PFDs for Application Identifier in a notification to the SMF.

Nnef_PFDManagement_Unsubscribe service operation

The Nnef_PFDManagement_Unsubscribe service operation allows the SMF to remove a subscription. The SMF provides the Application Identifier(s) it wants to remove the subscription for. The NEF removes the subscription and may delete any related resources.

Nnef_PFDManagement_Create service operation

The Nnef_PFDManagement_Create service operation allows an AF to create PFDs. The AF provides an AF ID, Application Identifier(s) and corresponding PFDs. If accepted by the NEF it stores the Application Identifier(s) and corresponding PFDs and responds to the AF with a Transaction Reference ID.

Nnef_PFDManagement_Update service operation

The Nnef_PFDManagement_Update service operation allows an AF to update PFDs. The AF provides a Transaction Reference ID, Application Identifier(s) and corresponding PFDs. The NEF stores the new PFDs and may update any subscribed SMFs.

Nnef_PFDManagement_Delete service operation

The Nnef_PFDManagement_Delete service operation allows the AF to request deletion of PFDs. The AF provides Transaction Reference ID and the NEF deletes the corresponding information.

13.2.14.3 Nnef_ParameterProvision service

This service is for allowing external party to provision of information which can be used for the UE in 5GS.

13.2.14.4 Nnef_ParameterProvision_Update service operation

The Nnef_ParameterProvision_Update service operation allows an AF to update the UE related information i.e., Expected UE Behaviour. The AF provides the GPSI, AF ID, Transaction Reference ID and Expected UE Behaviour parameters.

13.2.14.5 Nnef_Trigger service

Nnef_Trigger_Delivery service operation

The Nnef_Trigger_Delivery service operation allows the consumer to request that a trigger be sent to an application on a UE and it also implicitly subscribes to be notified about result of the trigger delivery attempt. The AF provides GPSI, AF ID, Trigger Reference Number, Application Port ID and the NEF responds with a Transaction Reference ID.

Nnef_Trigger_DeliveryNotify service operation

Nnef_Trigger_DeliveryNotify service operation allows the NEF to report the status of the trigger delivery to the application on the UE. The NEF includes the Transaction Reference ID and a Delivery Report.

13.2.14.6 Nnef_BDTPNegotiation service

Nnef_BDTPNegotiation create service operation

The Nnef_BDTPNegotiation create service operation allows the AF to request a background data transfer policy. The AF provides ASP Identifier, Volume per UE, Number of UEs, Desired time window and possibly the expected Network Area. The NEF responds with a Transaction Reference ID and one or more background data transfer policies.

Nnef_BDTPNegotiation update service operation

The Nnef_BDTPNegotiation update service operation allows the NF requests the selected background data transfer policy to be used. This service is only used if the NEF responded with several possible background data transfer policies in the Nnef_BDTPNegotiation Create Service Operation. The AF provides the Transaction Reference ID, ASP Identifier, and the selected background data transfer policy.

13.2.14.7 Nnef_TrafficInfluence service

The Nnef_TrafficInfluence service allows the NEF to provide authorization of requests, parameter mapping and possibility to influence traffic routing decisions.

Nnef_TrafficInfluence_Create service operation

The Nnef_TrafficInfluence_Create service operation allows the NEF to authorize the request and forward the request for traffic influence the relevant NF (that can execute the influence in traffic). The AF includes an AF Transaction Id and parameters specifying the traffic and the subscribers that should be influenced and parameter describing how traffic should be influenced. If authorized by the NEF it identifies the impacted NFs and forwards the request.

Nnef_TrafficInfluence_Update service operation

The Nnef_TrafficInfluence_Update service operation allows the NEF to authorize and forward the updated the traffic influence request. The AF provides the AF Transaction Id and any parameters to update. The NEF identifies the NFs to be updated and provides the update.

Nnef_TrafficInfluence_Delete service operation

The Nnef_TrafficInfluence_Delete service operation allows the AF to the request deletion of previous request for traffic influence. The AF provides the AF Transaction Id. The NEF authorizes the requests and forwards it to the relevant NFs.

Nnef_TrafficInfluence_Notify service operation

The Nnef_TrafficInfluence_Notify service operation allow the NEF to forward the UP path management event reports to AF. The NEF includes the AF Transaction Id,

UP path management event. The AF Transaction Id identifies the AF request for traffic influence that the event report is related to.

13.2.14.8 Nnef_ChargeableParty service

The Nnef_ChargeableParty service allows an NF to become the chargeable party for a data session for a UE.

Nnef_ChargeableParty create service operation

The Nnef_ChargeableParty create service operation allows an AF to request to become the chargeable party for a data session for a UE. The AF provides AF Identifier, UE IP address, Description of the application flows, Sponsor Information, Sponsoring Status. When accepted the NEF responds with a Transaction Reference ID.

Nnef_ChargeableParty update service operation

The Nnef_ChargeableParty update service operation allows the AF to change the chargeable party of a data session for a UE that has been previously created. The AF provides an AF Identifier, Transaction Reference ID and Sponsoring Status.

Nnef_ChargeableParty notify service operation

The Nnef_ChargeableParty notify service operation allows the NEF to report bearer level event(s) to the AF.

13.2.14.9 Nnef_AFsessionWithQoS service

The Nnef_AFsessionWithQoS service allows an NF to request a specific QoS for a session.

Nnef_AFsessionWithQoS create service operation

The Nnef_AFsessionWithQoS create service operation allows an AF to requests the network to provide a specific QoS for a session. The AF provides an AF Identifier, UE IP address, Description of the application flows and a QoS Reference. The NEF responds with an Transaction Reference ID.

Nnef_AFsessionWithQoS notify service operation

The Nnef_AFsessionWithQoS notify service operation allows the NEF to report bearer level event(s) to the AF.