Core

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Lets go into some detail about the 5G core.

One of the design principles of the 5G core is to have clear separation between the network functions responsible for user plane activity and the network functions responsible for control plane activity; control and user plane separation (CUPS). Therefore, this presentation is divided into a user plane part and a control plane part.

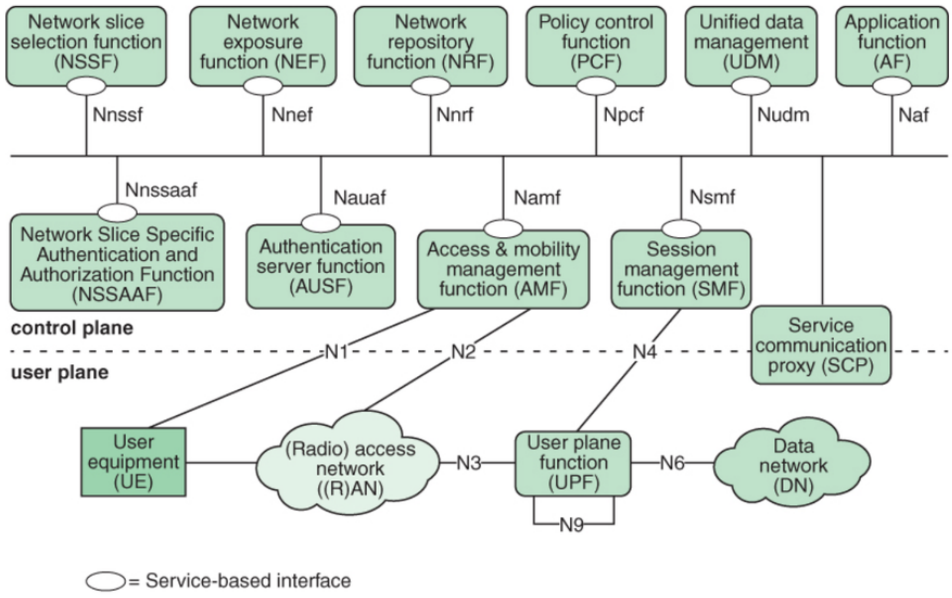


FIGURE 9.4 Non-Roaming 5G System Architecture

This page also contains a list of core network functions.

Mandatory Network Functions

- **Access and Management Function** (AMF) is like the Security Guard at a recipient desk.
  - Registration and Security
    - Responsible for authentication of UE, meaning determining if the UE can access services on this mobile network operator's equipment.
      - Provides a temporary ID, GUTI (Globally Unique Temporary ID) to UE while authenticating.
  - Subscriber Mobility
    - Keeps track of the location of UE based on cell ID (the ID of the cellular antenna area the UE is in).
      - Mobility management: handing off connection from one cellular antenna to another and from one DU to another.
    - If the UE is in idle mode (is off), the AMF approximates location through tracking and registration areas.
  - Access point for UE in that it forwards from the UE to any other network functions, as needed
- **Authentication Service Function** (AUSF) is like the badge scanner next to the reception desk.
  - After the AMF initiates connection, the AUSF is called to pick an authentication method to authenticate UE. Different UE will have different capabilities so the AUSF looks up the UE's methods in the Unified Data Management function (UDM).
- **Cell Broadcast Center Function** (CBCF) is the town siren.
  - This tool is used to send alarms to large number of UEs to warn about things like incoming tornadoes.
- **Session Management Function** (SMF) is like lawyer; it looks up rules and tells other NFs what those rules are.
  - Interacts with Policy Control Function (PCF) to

    - retrieve policies about to the sessions a particular UE is allowed to have,
    - retrieve charging instructions for the various sessions a UE has.
  - Responsible for creation, deletion, and modifications data sessions for the UE by
    - telling the UE the available entry points to the core (UPFs) so the UE can decide which to use.
    - telling the chosen UPF the rules for moving data for the various sessions,
      - including how to report data usage for charging.
  - Allocates IP address for UE, If needed, by looking up addresses on the relevant data network.
  - Performs authentication between UE and an application on a data network, if needed, by looking up authentication data in the UDM.
- **User Plane Function** (UPF) is like a traffic officer; it directs the flow of data packet by packet by following the laws.
  - User data flows from UE to gNB to UPF to DN, and back; the UPF is the only connection for user data flow in the core.
  - The UPF is the anchor point throughout mobility; no matter what cell or DU the mobile UE connects to, The UPF instance that serves a data flow remains constant.
  - The UPF enforces Quality of Service (QoS) rules, for example that the data packets a UE's session for an emergency call should be forwarded before packets for the same UE's session for a video game update.
  - The UPF follows rules about how to measure traffic flow for each session, and generates reports for other functions to use in calculating charging.
- **Unified Data Repository** (UDR) is the book of all UE information.
  - For each subscriber, the UDR has
    - authentication information and state (what stage of authentication the UE is in)
    - authorization information
    - a list of services have they subscribed, and
    - the data network details relevant to each
  - The UDR participates in registration by holding a copy of private keys necessary during authentication. The UE holds another, identical pair. The UE and AMF make sure the keys are hashed to the same value.
- **Unified Data Management** (UDM)
  - The UDM is the front end to the UDR; it is where user subscription data can be created, modified, or deleted.
  - The UDM has a module called Subscriber Identity De-Concealing Function (SIDF) for decrypting the subscriber concealed identity, allowing identification for accurate look up.
- **Policy Control Function** (PCF) is the law book.
  - Policies are retained here and SMF generally implements them.
  - The policies are about
    - quality of service (QoS) guaranteed by the provider to the UE.
    - charging. (Charging in money, not batter power.)
    - access control. (e.g. Giving access to high priority channels to fire departments for disaster relief.)
  - Has the ability to make real time (dynamic) decisions based current network conditions.
    - e.g. The PCF can ensure SMF denies a session to a UE to prevent exceeding the maximum number of allowed UE sessions of a particular kind.

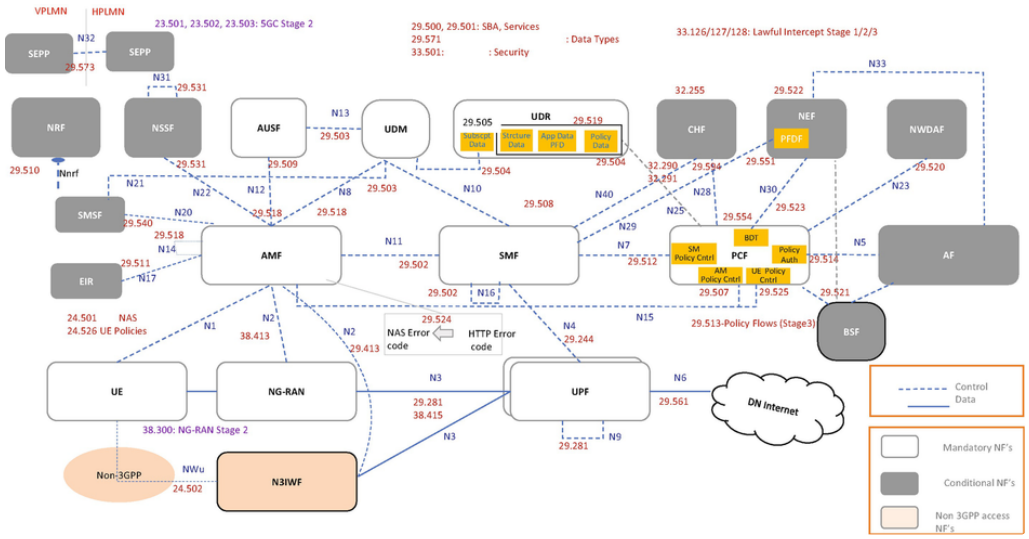


Diagram of a 5G core showing both mandatory and optional NFs, some of the modules those NFs contain in yellow, and in red the 3GPP document in which the function or module is defined.

Optional Network Functions

- **5G Equipment Identity Registry** (5G-EIR) is the doorman at the 5G core club.
  - Trusted UE are listed here.
  - UE that have been stolen or is otherwise not trusted is blacklisted.
- **Application Function** (AF) is a nickname or placeholder for a 3rd party application that can interact with the 5G core.
  - Accesses some data from the core through the network exposure function NEF.
  - Interacts directly with PCF to inform the PCF about policies for applications
    - including information about which edge data centers to use
- **Binding Support Function** (BSF) is a gossiper.
  - When data sessions involving network functions are set up, addresses are assigned to elements in the session. This assigning of addresses is called binding. The BSF keeps track of all the current bindings, and tells other network functions about those bindings upon request.
- **Charging Function** (CHF) is like a cashier; it looks at everything in the basket and calculates how much money is owed.
  - The charging data takes usage reports from the UPF along with charging policies from the PCF and calculates the charges incurred by a UE through its data sessions.
- **Location Management Function** (LMF) is like an air traffic controller; it calculates and keeps track of the position of UEs.
  - The LMF calculates the location of UE from radio information.
  - Resources for and timing of positioning activities are managed here.
  - Authorized external applications can request location data for e.g. emergency services.
- **Non-3GPP Inter Working Function** (N3IWF) is the network function that wears a base station disguise.
  - UE does not have to connect to a gNB (base station) to connect to a 5G core; the radio access network (RAN) is not the only option.
  - When UE connects to the 5G core through a cable, by WiFi, or any other non-5G RAN access, the N3IWF acts like the base station in the following sense:
    - The N2 connection goes from the N3IWF to the AMF.
    - The N3 connection goes from the N3IWF to the UPF.
- **Network Data Analytics Function** (NWDAF) is the guy in the basement with all the data,
  - The NWDAF collects data from other NFs, summarizes them, and makes its summaries available to other NFs.
  - Information from each slice is kept track of separately.

    - The policy control function (PCF) can have it's policies updated by these summaries.
    - The network slice selection function uses load level information for each slice to inform slice selection for new sessions.
- **Network Exposure Function** (NEF) is the press secretary; it is where application functions go to get information about the core.
    - NEF stores information about the capability of the network functions and slices (see below for network slicing).
    - APIs make that network capability information available to third parties.
- **Network Repository Function** (NRF) is the LinkedIn of network function instances; it lists all of the NF's out there, if they are available to work, and what they can do.
    - Each NF instance registers itself when instantiated, and updates its status (as activated or deactivated) periodically.
    - When a NF needs a service provided by another NF, it looks here to learn who out there provides the service.
    - The NRF provides a unique identification for each NF in the core network, and thereby provides an addressing system.
    - The NRF can provide authorization security for communication between other NFs by providing security tokens; when one NF wants to contact another, it first goes to the NRF and asks for a token, the NRF given the token if the NF has previously been authenticated, the NF sends the token in a request to the other NF it wants of communicate with, the other NF checks with the NF to see if the token is legitimate, and if so the communication proceeds.
- **Network Slice Selection Function** (NSSF) decides which universe from the multiverse a data session will live in.
    - A slices is a sub-network that functions alone as a network. That is, it is a logical network consisting of a subset of the set of all network function instances and a subset of the set of all access network points. A network operator could have several similar slices on top of each other, or very differently designed slices for different kinds of use of 5G, or can have both. (This is a sophisticated idea that takes some time to digest.)
    - When a UE requests a session with the network, it sends a slice selection request to the NSSF with preferred network slice selection information. The NSSF responds with a list of appropriate network slices. The UE chooses a slice from that list.
- **Security Edge Protection Proxy** (SEPP) is the ambassador between 5G networks.
    - When UE roams (meaning uses a 5G network in which it does not have a subscription to access the network where it does have a subscription) the SEPP is the intermediary for control plane communication.
        - messages from the home network's core go to the home network's SEPP, to the visited network's SEPP, and then to the visited network's core
        - and vice versa
        - Each core that facilitates roaming has a SEPP that is "on the edge of a core"
    - The SEPP hides information about the home network from the visited network, and vice versa.
    - The SEPP enforces roaming policies.
- **Service Communication Proxy** (SCP) is the interpreter between the NFs.
    - If a network operator buys network functions from several different providers, then direct communication between the NFs might not be smooth due to differences in implementation. The network operator can put a SCP in the core as a middle man in communication to smooth out those communication differences without needing to have their NF providers.
    - The presence of an SCP can help a network deal with times of heavy load through load balancing and overload handling.
- **Short Message Service Function** (SMSF) is the secret message messenger.
    - SMS is another name for text messages. Lots of new text message services that use internet protocol have been invented. (e.g. iMessage on iPhones). SMS is the old version of text messages that do not use internet protocol.
    - These SMS messages do not travel through the control plane; they travel from UE (to base station) to AMF to SMSF, and off to their destination.
    - The SMSF also checks on subscription data for SMS services.
- **UE Radio Capacity Management Function** (UCMF) is the technology nerd who knows the details of every device.
    - The UCMF stores a UE Radio Capability ID for each registered device on the network.
- **Unstructured Data Storage Function** (UDSF) is the copilot,
    - other network functions can store data that they might need later in the UDSF so that those other NFs can be as close to "stateless" as possible

        - being stateless is like being ready for what is next without remembering what happened in the past.
    - The term unstructured here refers to not needing to have a structure defined in international treaties; if software company 1 and 2 want to make UDSFs named UDSF1 and UDSF2, then UDSF1 might use one data structure and UDSF2 another data structure and no international treaties are broken.

As you see, there are many core functions in the core. Further, to improve performance, security, and quality, extra add-on functions/modules may be integrated in future.

Modules:

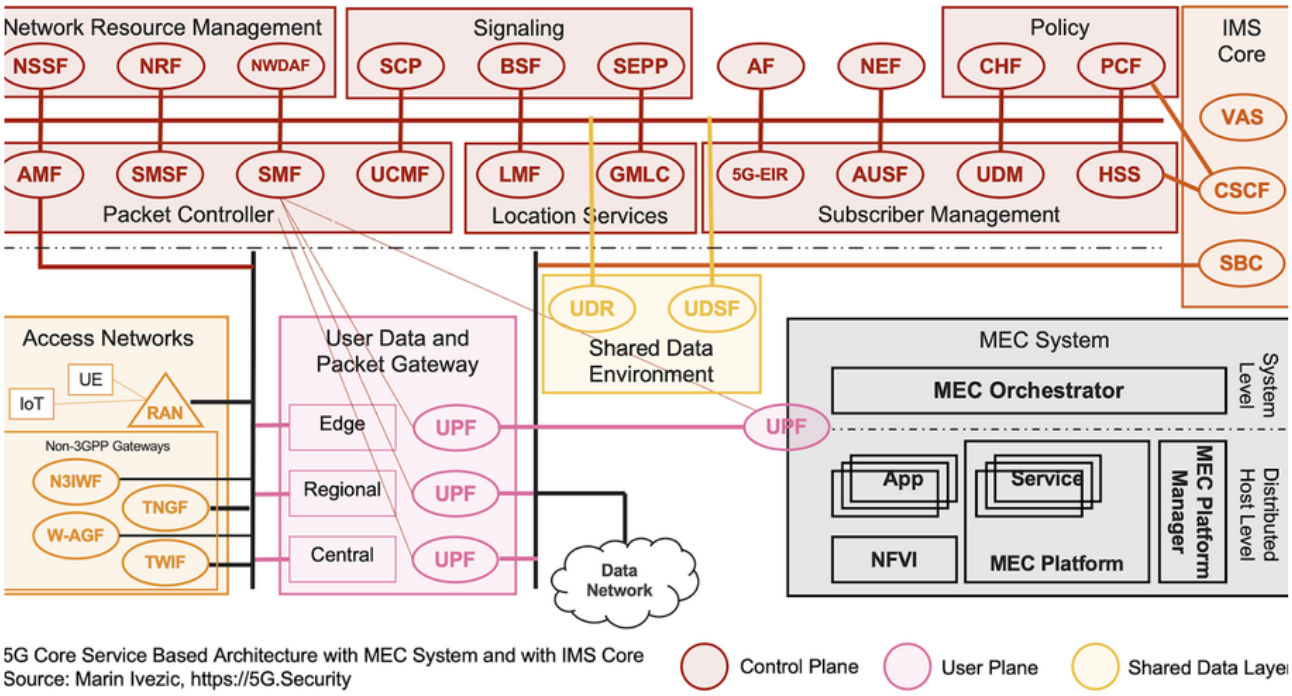
The network functions listed above run independently from each other; one can take a collection of NFs from vendor A and decide that the AMF from vendor B is better and replace just the AMF from vendor A with that from vendor B. The functions below are examples of functions that do not have this property; they are functions that are embedded inside NFs above and are thus not able to run independently. These functions that reside in NFs are referred to as modules.

- **Subscriber Identifier De-concealing Function** (SIDF) is a module in the UDM.
    - In roaming scenarios, the SIDF in the UDM of the home network takes in a concealed form of identity of a UE and gives out an un-concealed version (the true identity). Thus, the true identity of the UE is hidden from the visited network but not the home network.
- **SEcurity Anchor Function** (SEAF) is a module in the AMF.
    - In roaming scenarios, the SEAF in the AMF of the visited network
        - passes the UE's authentication information to the AUSF. (Namely the output of a hashing of the UE authentication keys.)
- **Authentication credential Repository and Processing and Processing Function** (ARPF) is a module in the UDM.
    - The ARPF delivers the copy of the UE's keys stored in the UDR to the AUSF so that the AUSF can hash the core's copy of the keys.
    - The AUSF compares the hashed values of the UE and of the core.

IMS Functions

The 5G core is not primarily designed for voice and video calls; it is primarily designed for (1) enhanced mobile broadband, (2) ultra reliable low latency communication, and (3) massive machine type communication. In fact, network functions to support calls are considered optional in the 5G core. In the diagram below, you will see the network functions presented above. On the top right you will also see network functions that together make up the IP Multimedia System (IMS) core. These functions are for voice calls, video calls, and for sms messages sent through the user plane (as opposed to the SMSF above). These functions are the same in 5G as they were in 4G because they were heavily optimized in 4G. They are often presented as application functions (AF) in literature about 5G.

- Home Subscriber Service (HSS) provides a relationship between UE identity and telephone number.
- Call Session Control Function (CSCF) handles call initiation, termination, and session management.
- Session Boarder Control (SBC) is the border between two networks; it translates data packets to voice signal for uplink and vice versa for downlink. It also performs security functions.
- Value Added Service functions (VAS) stands for any add-on products.



5G Core Service Based Architecture with MEC System and with IMS Core
Source: Marin Ivezic, https://5G.Security

The diagram above also shows some edge computing related functions that we will not discuss in this section.