Mobile Computing Architecture

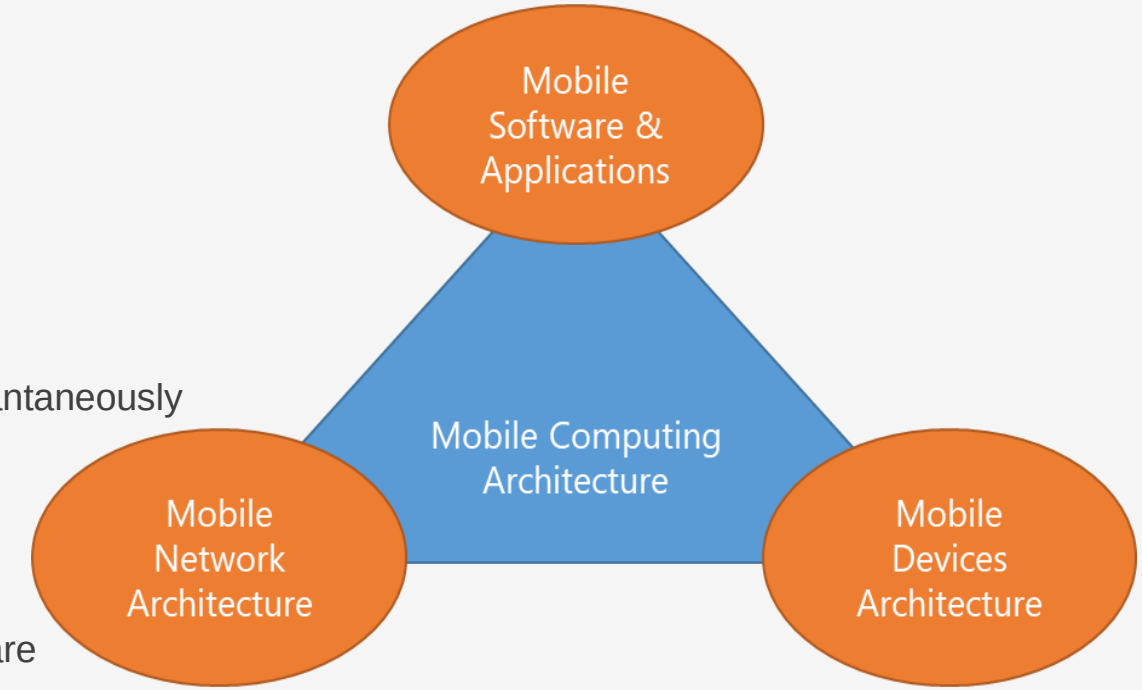
UW Bothell, WA

Lecture 4: 5G Network Architecture Overview

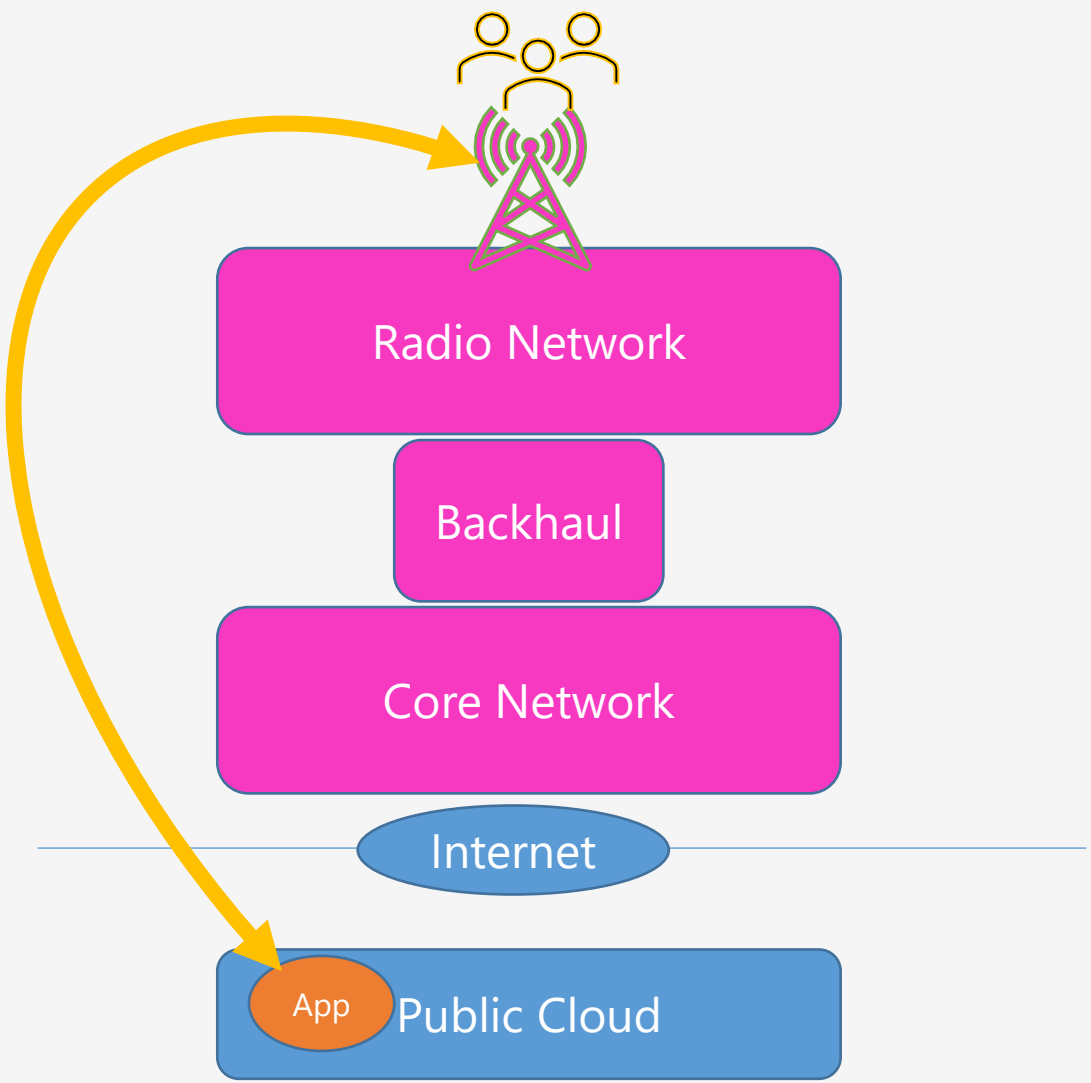
Mobile Computing Architecture

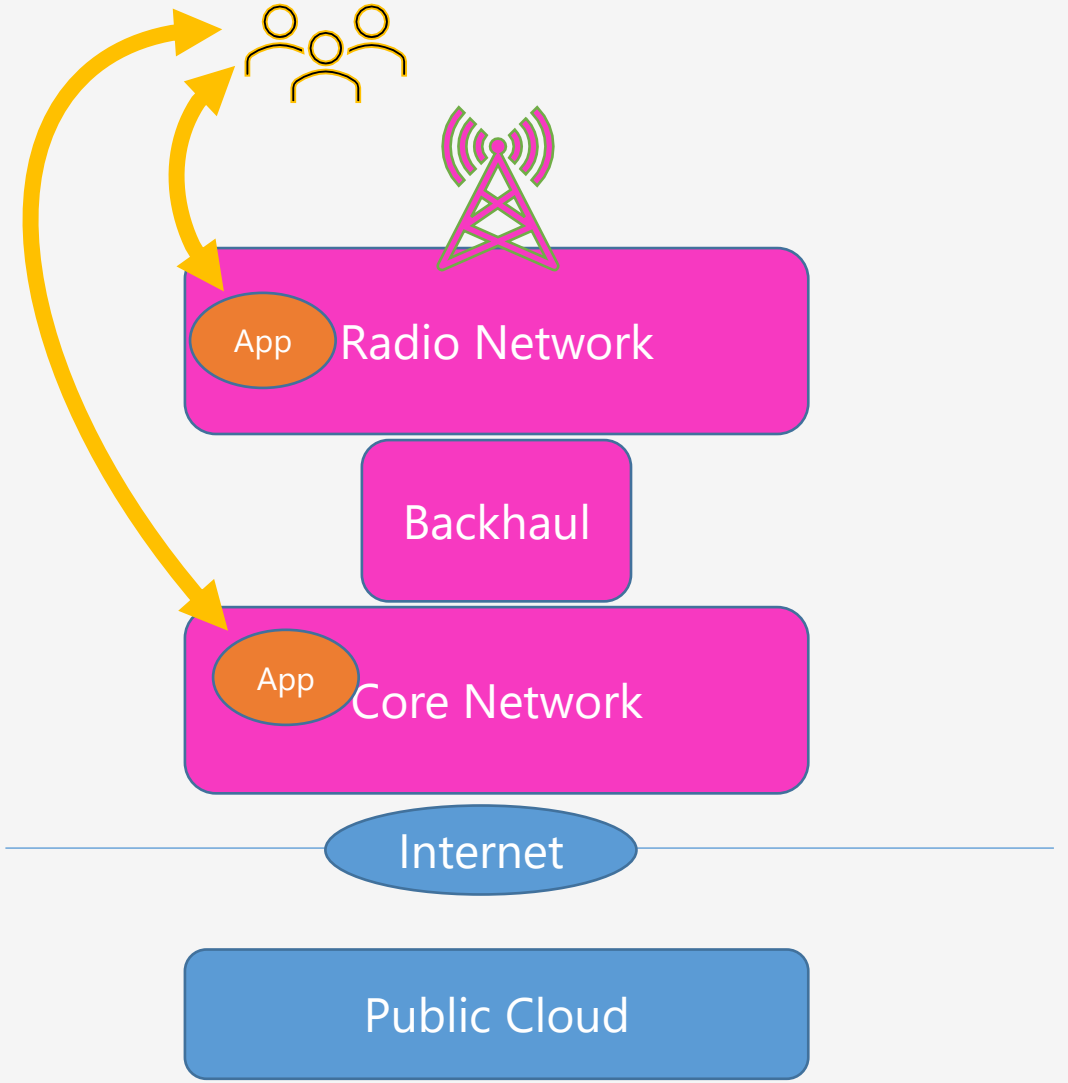
5G Objectives:

- High increased peak bit rate
- Ultra Low Latency
- Larger data volume per unit area (i.e. high system spectral efficiency)
- High capacity to allow more devices connectivity concurrently and instantaneously
- Lower battery consumption
- Better connectivity irrespective of the geographic region, in which you are
- Larger number of supporting devices
- Lower cost of infrastructural development

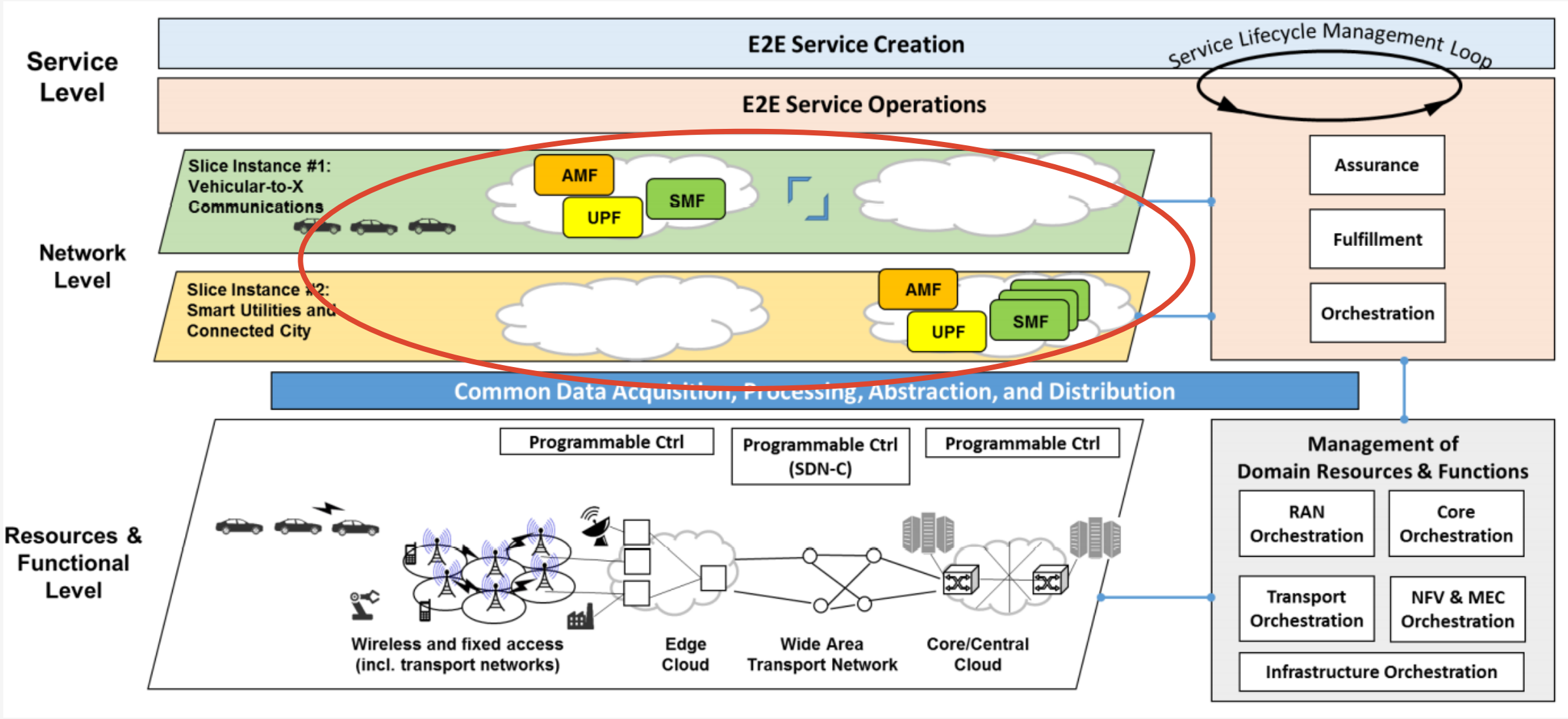


Recall: 5G – Edge Computing Intro [Latency]

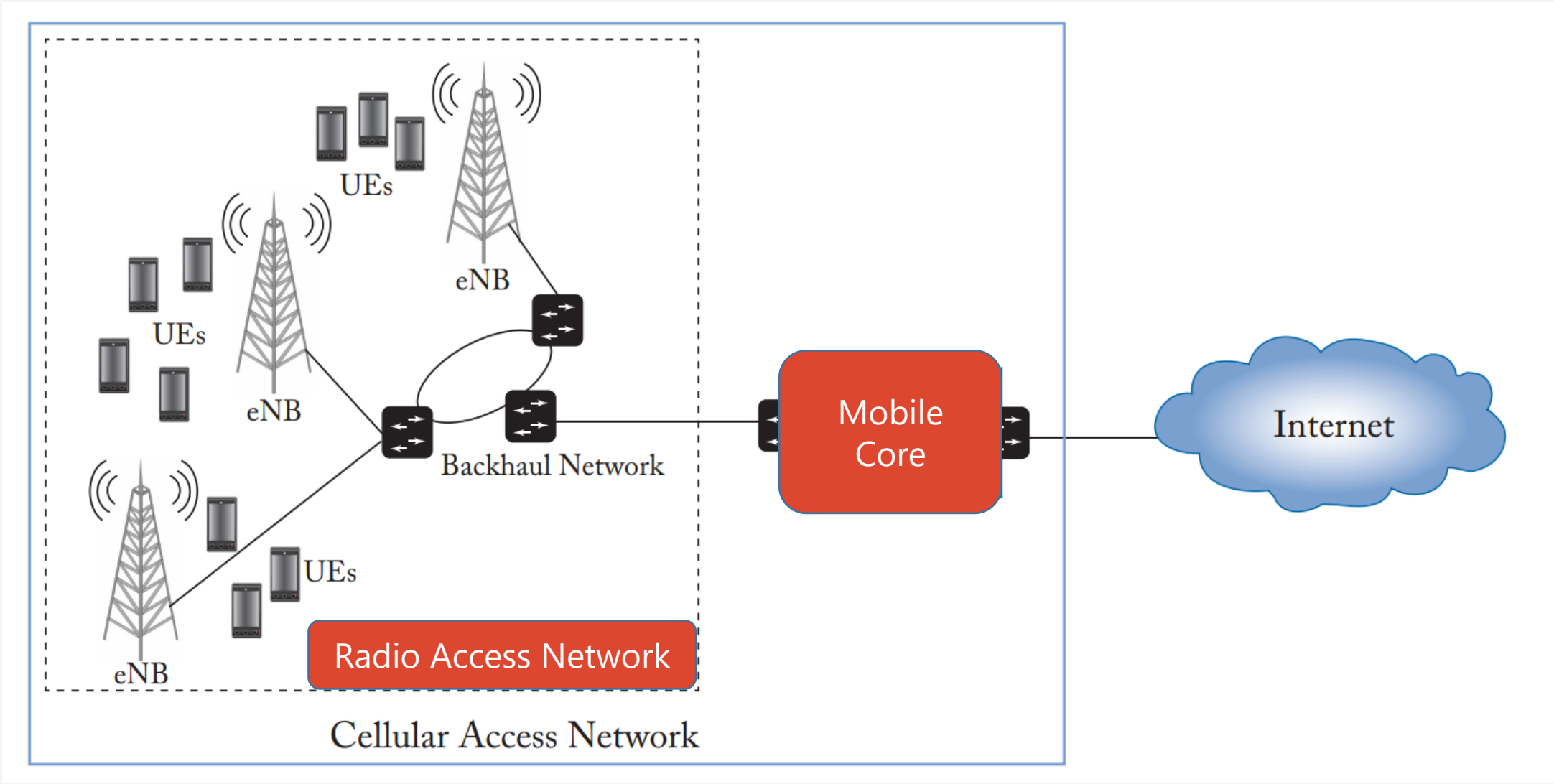




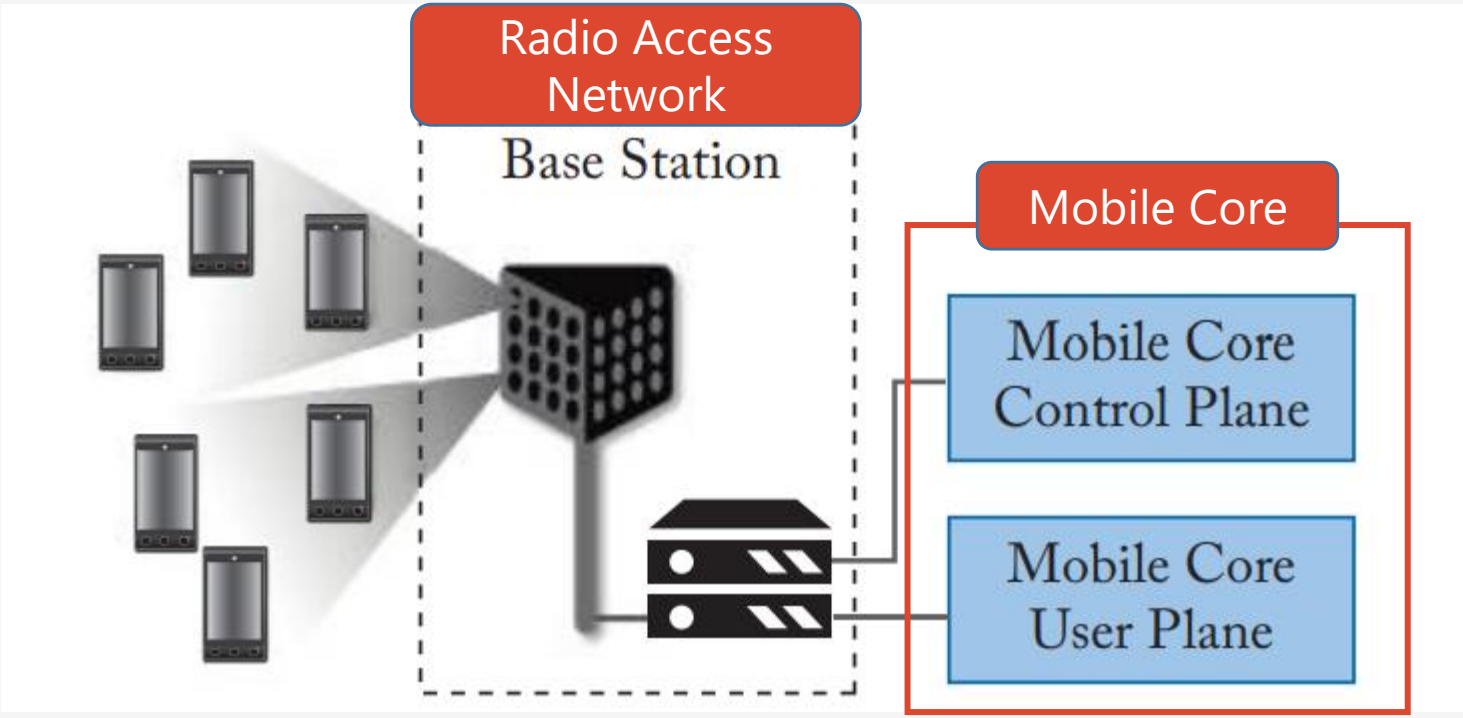
5G Service Based Architecture



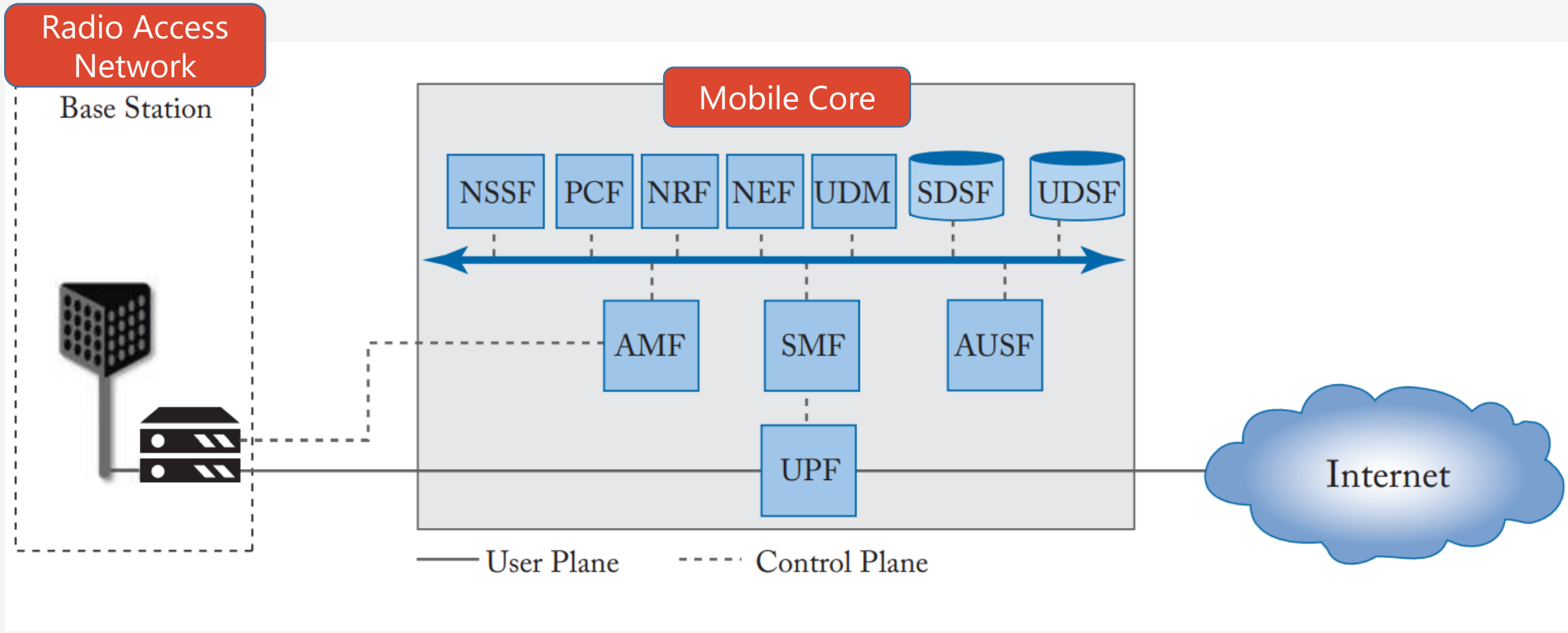
Basic 4G/5G Architecture



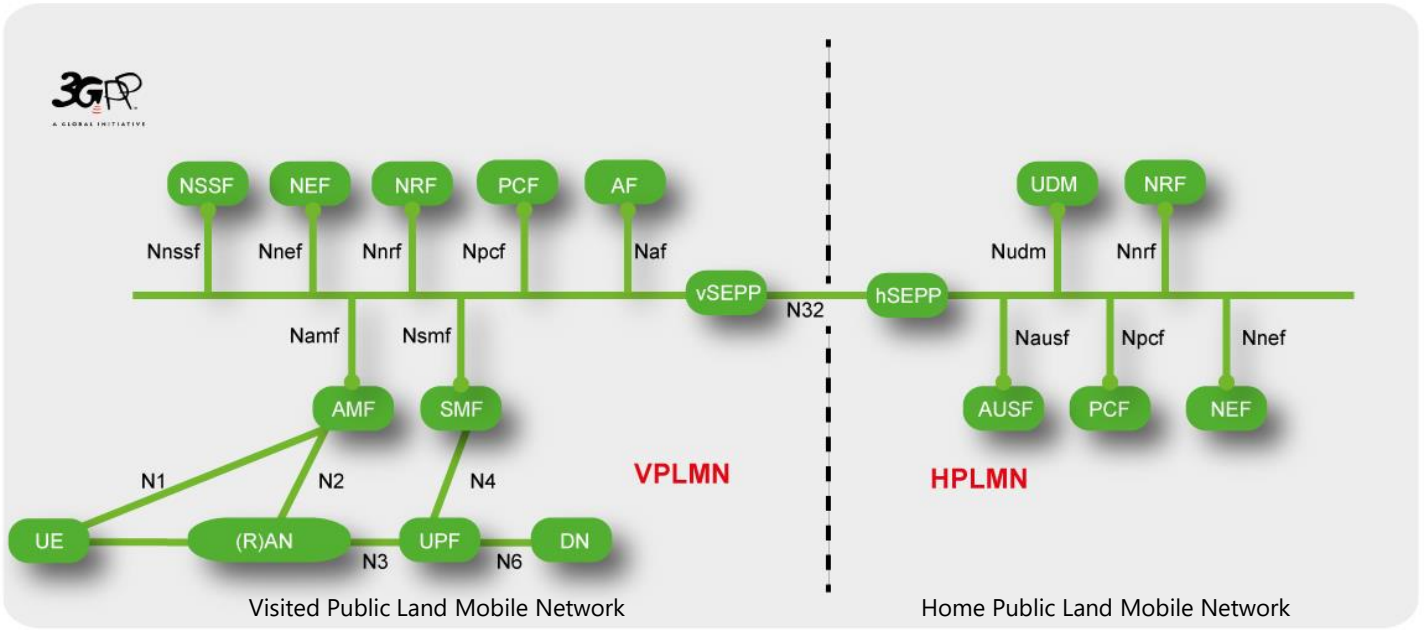
Basic 4G/5G Architecture – Control Plane and User Plane Split



5G Architecture – Network Functions



3GPP 5G Mobile Network Architecture
Network Functions and Interfaces



- User Equipment (UE) [mobile phones…]
- (Radio) Access Network ((R)AN) in LTE is called eNodeB; in 5G is called **gNodeB**
- User Plane Function (UPF)
- Data Network (DN), e.g. operator services, Internet

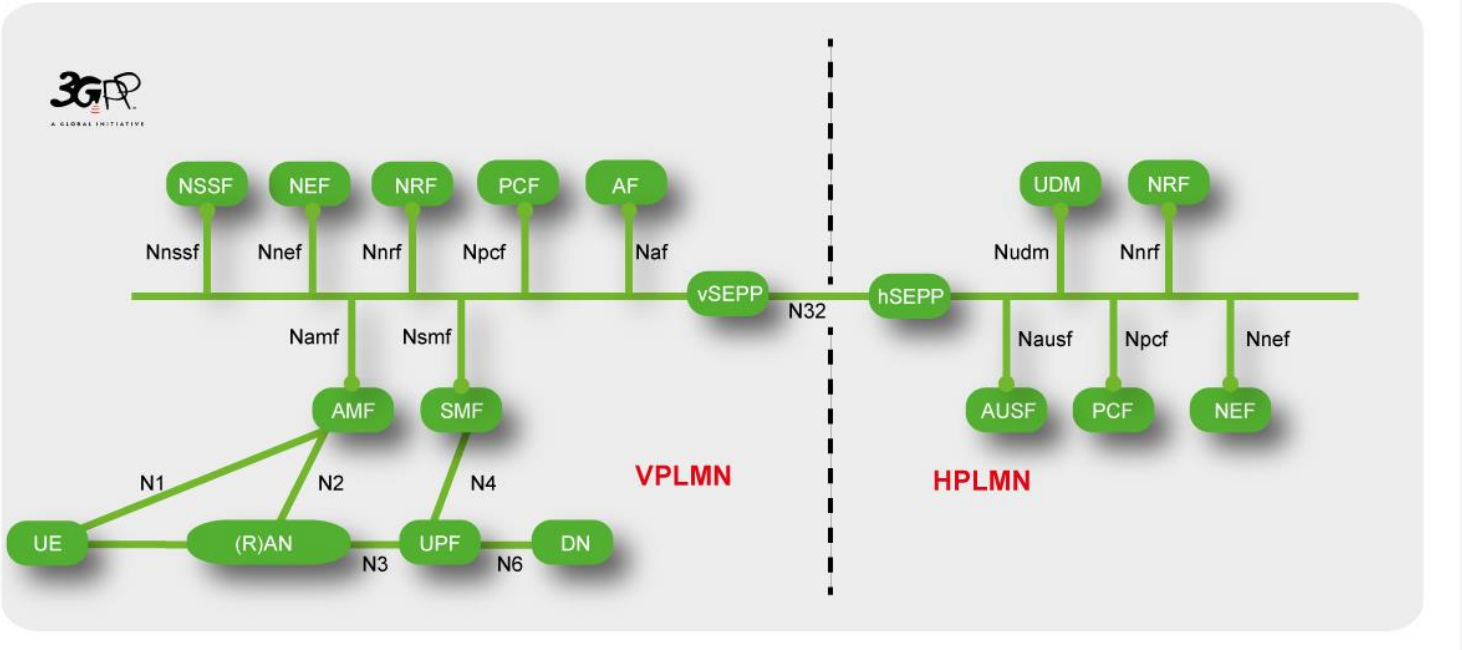
- Access and Mobility Management Function (AMF)
- Session Management Function (SMF)
- Unified Data Repository (UDR)
- Authentication Server Function (AUSF)
- Unified Data Management (UDM)

- Application Function (AF)
- Network Repository Function (NRF)
- Policy Control Function (PCF)
- Network Exposure Function (NEF)
- Network Slice Selection Function (NSSF)

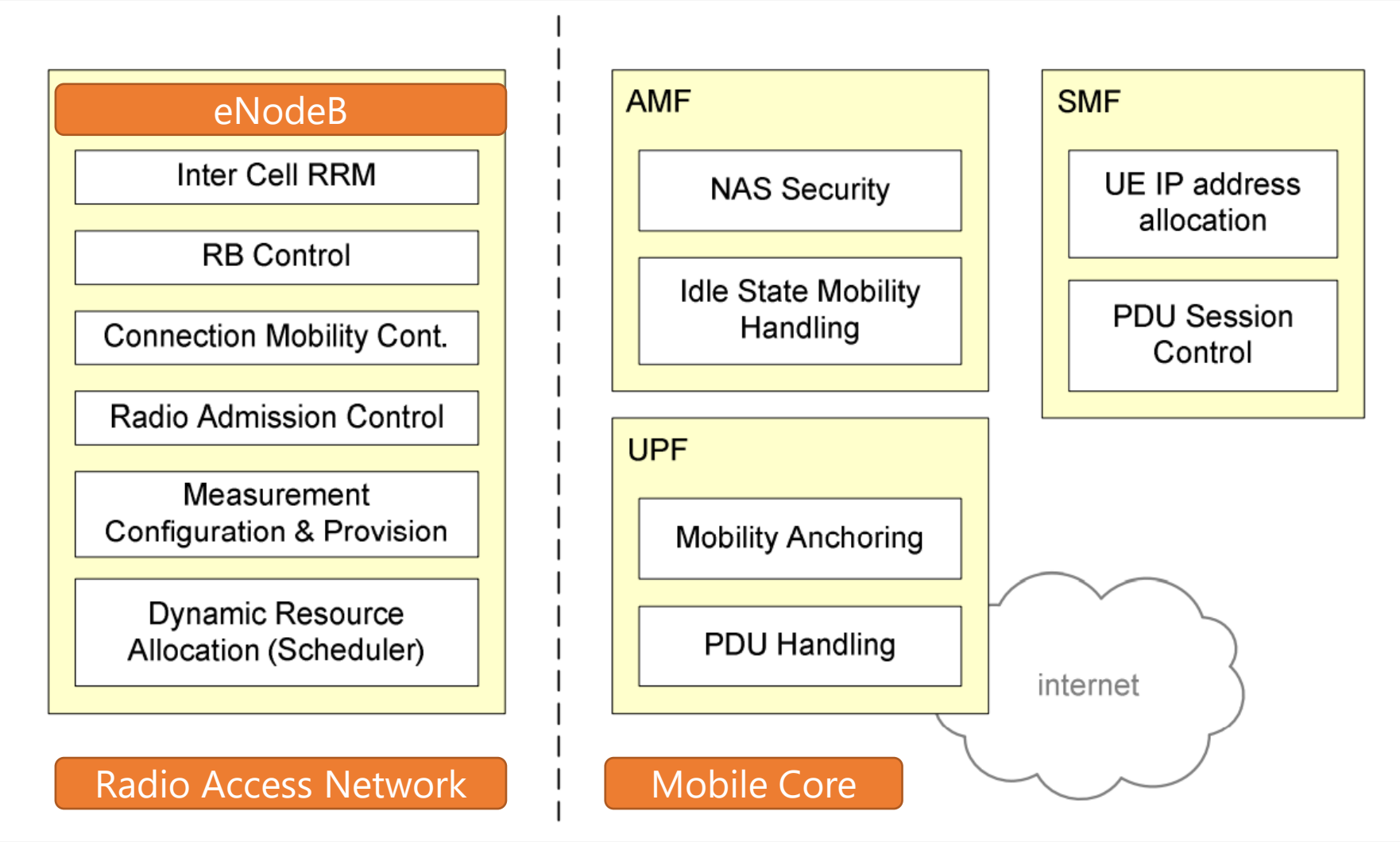
5G Mobile Network Architecture – Standards and Drivers

3GPP 5G mobile system architecture is service based. The network elements are defined as network functions that offer their services via interfaces (for example APIs, etc.) of a common framework to any network functions that are permitted to make use of these provided services.

- Modularity
- Reusability | Recursive
- Self-containment of network functions
- Virtualization and software technologies
- Network Slicing



3GPP 5G Mobile Network Architecture
Functional Split: RAN and 5G Core (5GC)

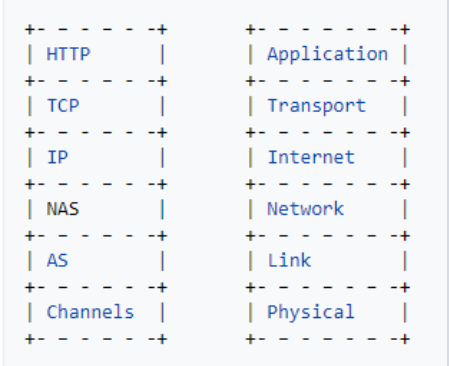


5G Network Architecture

Access and Mobility Function (AMF)

The Access and Mobility Management function (AMF) includes the following Control Plane functionality:

- Termination of RAN Control Plane interface (N2)
- Termination of NAS (N1). Non-access stratum (NAS) is a functional layer in the wireless telecom protocol stack between the core network and user equipment. This layer is used to manage the establishment of communication sessions and for maintaining continuous communications with the user equipment as it moves.



- Registration management
- Connection management
- Reachability management
- Mobility Management
- Lawful intercept (for AMF events and interface to LI System)
- Provide transport for SM messages between UE and SMF
- Transparent proxy for routing SM messages
- Support for Network Slice Authentication & Authorization

- Access Authentication
- Access Authorization
- Security Anchor Functionality (SEAF) as specified in TS 33.501
- Location Services management for regulatory services
- Provide transport for Location Services messages between UE and LMF as well as between RAN and LMF
- EPS Bearer ID allocation for interworking with 4G
- UE mobility event notification
- Support for Control Plane Cellular IoT Optimization
- Support for User Plane Cellular IoT Optimization

5G Network Architecture
Session Management Function (SMF)

The Session Management function (SMF) includes the following Control Plane functionality:

- Session Management e.g. Session Establishment, modify and release, including tunnel maintain between UPF and AN node.
- UE IP address allocation & management (including optional Authorization)
- Functionality to respond to Address Resolution Protocol (ARP) requests and / or IPv6 requests
- Configures traffic steering at UPF to route traffic to proper destination
- Termination of interfaces towards Policy control functions
- Lawful intercept
- Charging data collection and support of charging interfaces
- Control and coordination of charging data collection at UPF
- Termination of SM parts of NAS messages

- Downlink Data Notification
- Initiator of AN specific SM information, sent via AMF over N2 to AN
- Support for Control Plane CIoT 5GS Optimisation.
- Support of header compression.
- Provisioning of external parameters (Expected UE Behaviour parameters or Network Configuration parameters).
- **Roaming functionality:**
  - Handle local enforcement to apply QoS SLAs (VPLMN).
  - Charging data collection and charging interface (VPLMN).
  - Lawful intercept (in VPLMN for SM events and interface to LI System)
  - Support for interaction with external DN for transport of signalling for PDU Session authentication/authorization by external DN
  - Instructs UPF and NG-RAN to perform redundant transmission on N3/N9 interfaces

5G Network Architecture

User Plane Function (UPF)

The User Plane Function (UPF) includes the following User Plane functionality:

- Termination of RAN User Plane for SMF (N4)
- External PDU Session point of interconnect to Data Network via N6 interface
- Packet routing & forwarding
- Anchor point for Intra-/Inter-Radio Access mobility
- Allocation of UE IP address/prefix (if supported) in response to SMF request
- Packet inspection
- User Plane part of policy rule enforcement, e.g. Gating, Redirection, Traffic steering)
- Lawful intercept
- Traffic usage reporting
- QoS handling for user plane, e.g. UL/DL rate enforcement, QoS marking in DL
- Transport level packet marking in the uplink and downlink

- Downlink packet buffering and downlink data notification triggering.
- Sending and forwarding of one or more "end marker" to the source NG-RAN node.
- Functionality to respond to Address Resolution Protocol (ARP) requests and / or IPv6 Neighbour Solicitation requests based on local cache information for the Ethernet PDUs. The UPF responds to the ARP and / or the IPv6 Neighbour Solicitation Request by providing the MAC address corresponding to the IP address sent in the request.
- Packet duplication in downlink direction and elimination in uplink direction

5G Network Architecture

Network Repository Function (NRF) and Unified Data Management (UDM)

Unified data management (UDM) manages network user data in a single, centralized element. UDM can be paired with the user data repository (UDR) which stores the user data such as customer profile information, customer authentication information, and encryption keys for the information. UDM resides on the control plane and utilizes microservices to communicate between the user plane and the control plane. A stateful UDM keeps data on hand locally, while a stateless UDM stores data externally in the UDR.

The Unified Data Repository (UDR) supports the following functionality:

- Storage and retrieval of subscription data by the UDM
- Storage and retrieval of policy data by the PCF
- Storage and retrieval of structured data for exposure
- Application data (including Packet Flow Descriptions (PFDs) for application detection, AF request information for multiple UEs, 5GLAN group information for 5GLAN management)
- Storage and retrieval of NF Group ID corresponding to subscriber identifier (e.g. IMPI, IMPU, SUPI)

The Unified Data Repository is located in the same PLMN as the NF service consumers storing in and retrieving data from it using Nudr. Nudr is an intra-PLMN interface.

The Unified Data Management (UDM) includes support for the following functionality:

- Generation of Authentication Credentials
- User Identification Handling for each subscriber in the 5G system
- Access authorization based on subscription data (e.g. roaming restrictions).
- UE's Serving NF Registration Management (e.g. storing serving AMF for UE, storing serving SMF for UE's PDU Session)
- Support service/session continuity
- SMS delivery support.
- Lawful Intercept Functionality
- Subscription management
- SMS management
- Support of external parameter provisioning (Expected UE Behaviour parameters or Network Configuration parameters).

5G Network Architecture

Authentication Server Function (AUSF)

Authentication and Authorization Definitions

The 5G system shall satisfy the following requirements.

Subscription authentication: The serving network shall authenticate the **Subscription Permanent Identifier (SUPI)** in the process of authentication and key agreement between UE and network.

Serving network authentication: The UE shall authenticate the serving network identifier through implicit key authentication.

UE authorization: The serving network shall authorize the UE through the subscription profile obtained from the home network. UE authorization is based on the authenticated SUPI.

Serving network authorization by the home network: Assurance shall be provided to the UE that it is connected to a serving network that is authorized by the home network to provide services to the UE. This authorization is 'implicit' in the sense that it is implied by a successful authentication and key agreement run.

- The Authentication Server Function (AUSF) is in a home network and performs authentication with a UE. It makes the decision on UE authentication, but it relies on backend service for computing the authentication data and keying materials when 5G-AKA or EAP-AKA' is used
- Unified data management (UDM) the Authentication Credential Repository and Processing Function (ARPF), which selects an authentication method based on subscriber identity and configured policy and computes the authentication data and keying materials for the AUSF
- 5G authentication framework uses three authentication methods: 5G-AKAEAP-AKA', and EAP-TLS [security: later chapters]

5G Network Architecture

Policy Control Function (PCF)

The Policy Control Function (PCF) includes the following functionality:

- Supports unified policy framework to govern network behaviour
- Accesses subscription information relevant for policy decisions in a Unified Data Repository (UDR)
- Provides policy rules to Control Plane function(s) to enforce them
- Policy and charging control for a service data flows
- Session event reporting to the Application Function (AF)
- The PCF provides authorized QoS for a service data flow. The authorization of QoS resources based on AF information described in clause 6.2.1.0 of TS 23.203 applies with the clarification that the subscription information is retrieved as defined in TS 23.501
- At reception of the service information from the AF, if configured through policy, the PCF determines the Maximum Packet Loss Rate for Uplink and Downlink based on the service information e.g. codec and sends it to SMF along with the policy control rules
- The PCF support for usage monitoring control in clause 6.2.1.0 of TS 23.203 applies. The PCF may authorize an application service provider to request specific PCC decisions (e.g. authorization to request sponsored IP flows, authorization to request QoS resources) based on sponsored data connectivity profile from the UDR. For sponsored data connectivity, the PCF may receive a usage threshold from the AF. If the AF specifies a usage threshold, the PCF shall use the Sponsor Identity to construct a Monitoring key for **monitoring the volume, time, or both volume and time of user plane traffic, and invoke usage monitoring on the SMF**
- The PCF shall notify the AF when the SMF reports that a usage threshold for the Monitoring key is reached provided that the AF requests to be notified for this event. If the usage threshold is reached, **the AF may terminate the AF session or provide a new usage threshold to the PCF**

5G Network Architecture

RAN: gNodeB

ETSI TS 138 300

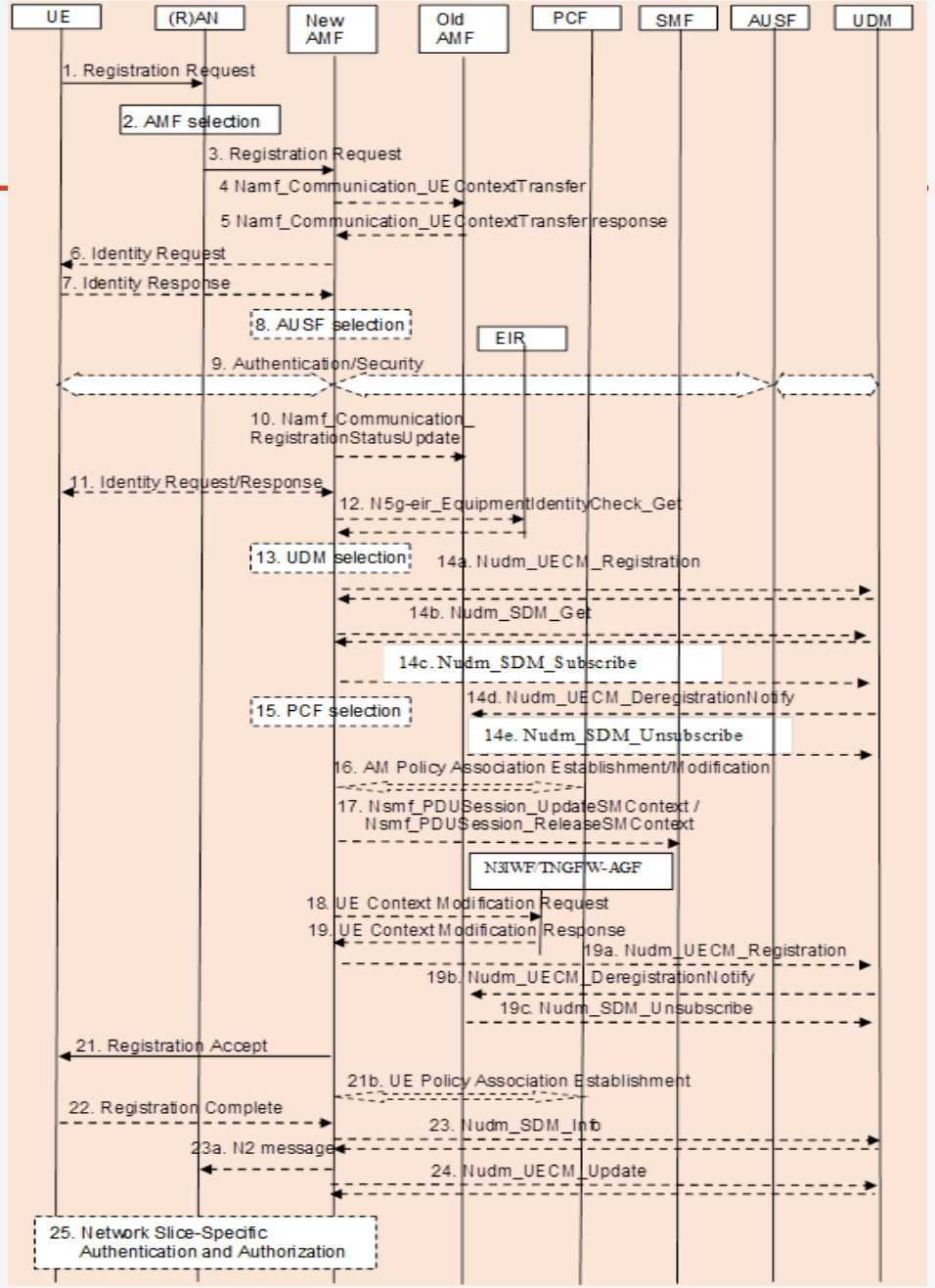
The gNodeB hosts the following functions:

- Functions for Radio Resource Management: Radio Bearer Control, Radio Admission Control, Connection Mobility Control, Dynamic allocation of resources to UEs in both uplink and downlink (scheduling)
- IP header compression, encryption and integrity protection of data
- Selection of an AMF at UE attachment when no routing to an AMF can be determined from the information provided by the UE
- Routing of User Plane data towards UPF(s)
- Routing of Control Plane information towards AMF
- Connection setup and release
- Scheduling and transmission of paging messages
- Scheduling and transmission of system broadcast information (originated from the AMF or OAM);
- Measurement and measurement reporting configuration for mobility and scheduling
- Transport level packet marking in the uplink
- Session Management
- Support of Network Slicing
- QoS Flow management and mapping to data radio bearers
- Support of UEs in RRC_INACTIVE state
- Distribution function for NAS messages
- Radio access network sharing
- Dual Connectivity
- Tight interworking between NR and E-UTRA.

5G Network Architecture
Example: UE Registration

UE Registration as one example of call flow..

- UE Sends a Registration Request
- Goes to RAN (gNodeB)
- gNodeB communications with AMF (control function)
- AMF selects AUSF
- Authentication of UE
- AMF Selects a UDM and registers/subscribers the UE
- AMF Selects a PCF and establishes context
- AMF sends the Registration Accept back to UE
- UE send Registration Complete



3GPP TS 23.502

Lecture 4 Reading & Assignment

Reference 3GPP TS 38.410