5G NSA Core Network Architecture and Step by Step process
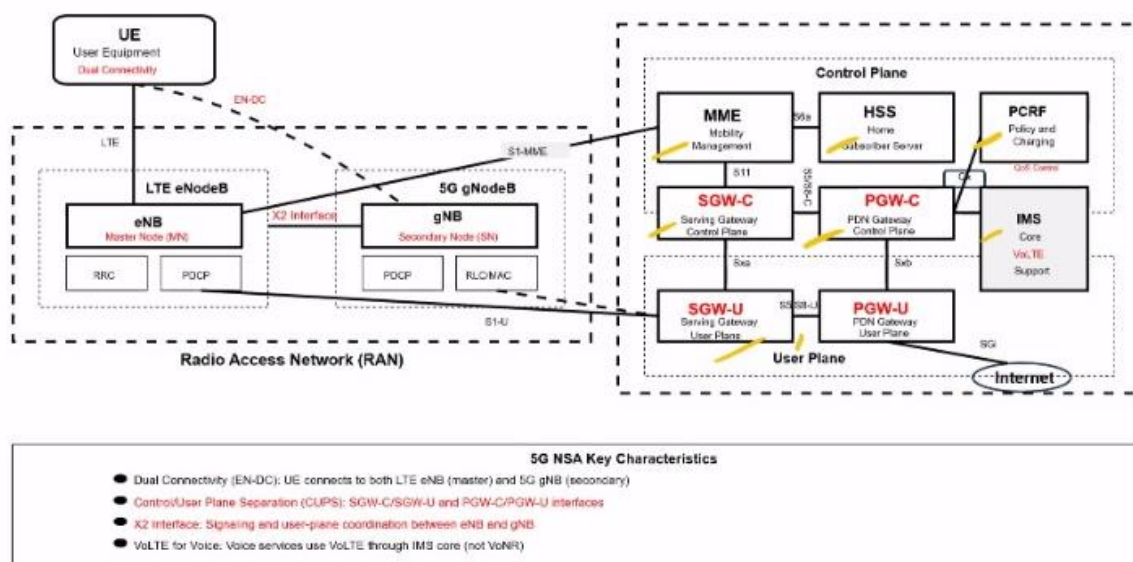
Fig1: Network Architecture

The 5G NSA (Non-Standalone) Core Network Architecture enables 5G deployment using existing 4G LTE infrastructure. In this model, LTE handles control plane functions like signalling and mobility, while 5G New Radio (NR) delivers high-speed data. Using EN-DC (E-UTRAN New Radio – Dual Connectivity), the user device connects to both the LTE eNodeB (Master Node) and 5G gNodeB (Secondary Node) simultaneously. This allows operators to offer faster data speeds and improved performance without building a new 5G core network. NSA is a cost-effective and faster solution for early 5G rollout. However, it lacks full 5G features like ultra-low latency and network slicing, which are available only in the 5G Standalone (SA) architecture. NSA is a key step toward full 5G implementation.

Overview of NSA Architecture:

User Equipment (UE):

- **Function**: Mobile phone or IoT device that connects to the network.
- **If missing**: No communication can start.
- **Real Example**: A smartphone supporting both LTE and 5G (e.g., iPhone 14).
- **End-to-End Role**: Sends/receives data, initiates call, requests services.

Radio Access Network (RAN):

1. LTE eNodeB (eNB) – Master Node (MN):

- **Function**: Handles control plane signaling and connects UE to core.
- **If missing**: No connection initiation, mobility management will fail.
- **Real Example**: 4G tower providing basic voice and data services.
- **Role**: Controls session establishment and mobility (handover).

2. LTE eNodeB (eNB) — 4G Tower (Master Node):

- **Function**: Handles control signals like authentication, handovers, and session setup.
- **If missing**: Device cannot initiate or maintain network connection; mobility and session control will fail.
- **Real Example**: 4G cellular towers providing coverage for calls and data.

2. 5G gNodeB (gNB) – Secondary Node (SN):

- **Function**: Provides high-speed data via 5G.
- **If missing**: No 5G benefits like high speed or low latency.
- **Real Example**: 5G antennas on rooftops/street poles.
- **Role**: Boosts data throughput, supports EN-DC.

3. X2 Interface:

- **Function**: Interface between eNB and gNB to coordinate control and data.
- **If missing**: No synchronization, handover issues.
- **Real Example**: Software-defined links between LTE and 5G base stations.

Core Network:

Control Plane:

1. MME (Mobility Management Entity):

- **Function**: Authenticates UE, manages sessions and mobility.
- **If missing**: No user authentication or mobility support.
- **Real Example**: Handles handover from one tower to another when moving.

2. HSS (Home Subscriber Server):

- **Function**: Stores user data like subscription info, authentication keys.
- **If missing**: No user verification.
- **Real Example**: SIM card validation when you turn on your phone.

3. SGW-C (Serving Gateway - Control Plane):

- **Function**: Control signalling for user traffic routing.
- **If missing**: Cannot manage data paths for user traffic.
- **Real Example**: Acts like traffic control in a city.

4. PGW-C (PDN Gateway - Control Plane):

- **Function**: Allocates IP addresses, manages policies.
- **If missing**: No IP allocation or service access.
- **Real Example**: IP configuration server in corporate networks.

5. PCRF (Policy and Charging Rules Function):

- **Function**: Applies policies (QoS, throttling), handles billing.
- **If missing**: No QoS control or data usage enforcement.
- **Real Example**: Data cap enforcement or speed throttle by telecom.

6. IMS (IP Multimedia Subsystem):

- **Function**: Enables VoLTE (Voice over LTE).

- **If missing**: No voice calls over LTE/5G, fallback to 2G/3G.

- **Real Example**: Making calls over Jio VoLTE.

User Plane:

1. SGW-U (Serving Gateway – User Plane):

- **Function**: Routes user data to/from eNB/gNB.
- **If missing**: No user data delivery.
- **Real Example**: Handles the actual internet traffic for the user.

2. PGW-U (PDN Gateway – User Plane):

- **Function**: Forwards user data between internet and RAN.
- **If missing**: UE can't access the internet.
- **Real Example**: Exit point of the mobile network to the web.

Internet

- **Function**: Final destination of data (websites, apps, etc.).
- **Real Example**: Accessing Google, YouTube, Zoom, etc.

Now let us understand flow from end-to-end journey of streaming YouTube video: -

1. **You (UE)** decide to stream a YouTube video.

2. UE connects to the nearest **eNB (4G tower)** to request access.

3. **eNB** communicates with the **MME**, which manages mobility and session setup.

4. **MME** checks user information with **HSS** (Are you subscribed? Are you authenticated?).

5. **PCRF** is contacted to confirm whether you have data available and what quality can be allowed.

6. Once verified, **PGW-C** assigns you an IP address, just like giving you a passport to access the internet.

7. **SGW-C** and **PGW-C** determine the best route for your data to travel.

8. **MME** then coordinates with the **X2 Interface**, which allows your data plane to be handed over to **gNB (5G)** for high-speed transfer.

9. **gNB** starts sending the video content through **SGW-U** (delivery van) and **PGW-U** (post office).

10. If it's a voice or video call instead of YouTube, **IMS** handles the communication.

11. Finally, the video reaches you smoothly from the **INTERNET**, and you're now watching your content in HD.
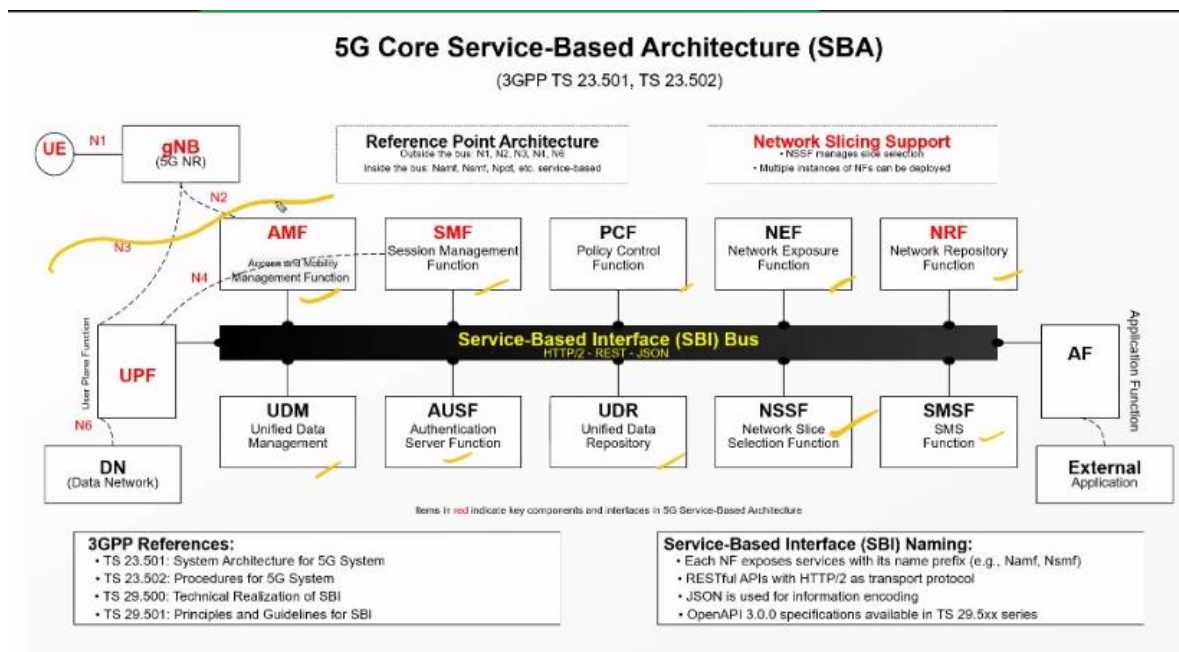
5G Core Network Service-Based Architecture (SBA)

Fig: Service-Based Architecture

Service-Based Architecture (SBA) is the core architectural model of the 5G Core Network. It replaces the traditional point-to-point interfaces with modular, cloud-native **network functions (NFs)** that communicate via **RESTful APIs** over HTTP/2. Each NF provides services (e.g., authentication, session management) that can be dynamically discovered and used by other NFs through a **central repository** called the **Network Repository Function (NRF)**. This design enables flexibility, scalability, and rapid deployment of new features. SBA also supports **network slicing** and **multi-vendor interoperability**, making the core network more agile and programmable. It mirrors microservice-based architecture seen in IT/cloud, ensuring that telecom systems evolve with modern software principles like **service discovery**, **statelessness**, and **orchestration**.

COMPONENT-BY-COMPONENT EXPLANATION:

1. UE (User Equipment):

- **What it is:** Your mobile phone, smartwatch, smart car, or any 5G device.
- **Technical Role:** Starts communication, sends registration request to the network.
- **Analogy:** You (the passenger) walk into the airport to catch a flight.
- **If missing:** No one is there to request services—network is idle.

2. gNB (5G Tower):

- **What it is:** The radio station connecting UE to the 5G Core.
- **Technical Role:** Handles radio signals, forwards control messages to AMF, and user data to UPF.
- **Analogy:** The gate that lets you into the airport and passes your luggage to the right conveyor belts.
- **If missing:** No way to enter the airport; devices can't reach core services.

3. AMF (Access and Mobility Function):

- **What it is:** Core node responsible for access and mobility handling.
- **Technical Role:** Handles device registration, connection setup, mobility (handover).
- **Analogy:** The immigration desk that checks your passport and grants you permission to enter.
- **If missing:** Passengers won't be allowed into the airport; network can't authenticate devices.

4. SMF (Session Management Function):

- **What it is:** Core node that manages session rules and IP address allocation.
- **Technical Role:** Establishes a PDU session (internet connection), assigns IP, and tells UPF how to route data.
- **Analogy:** The officer who assigns your seat and prints your boarding pass.
- **If missing:** You're in the airport, but can't board the plane (no IP session).

5. UPF (User Plane Function):

- **What it is:** Handles the actual flow of data to/from internet (Data Network).
- **Technical Role:** Forwards user data (video, audio, web) to destination (internet or cloud).
- **Analogy:** The luggage conveyor system that takes your bags to the plane and delivers them at your destination.
- **If missing:** Your data never leaves the airport—you're authenticated but offline.

6. UDM (Unified Data Management):

- **What it is:** Stores subscriber info, profiles, and service permissions.
- **Technical Role:** Provides data to AMF and AUSF to check if a user is allowed on the network.
- **Analogy:** The backend database where your travel history, bookings, and preferences are stored.
- **If missing:** Airport can't verify if you're a valid passenger; access denied.

7. AUSF (Authentication Server Function):

- **What it is:** Handles user authentication using credentials from UDM.
- **Technical Role:** Runs 5G-AKA or EAP protocols to verify SIM authenticity.
- **Analogy:** A machine that checks if your passport is real.
- **If missing:** Any random person can pretend to be someone else—huge risk!

8. PCF (Policy Control Function):

- **What it is:** Central brain for policy decisions and enforcement.
- **Technical Role:** Tells SMF/AMF what kind of QoS to apply, data limits, and priority levels.
- **Analogy:** Officer, ensuring you stick to your seat class (Economy/Business) and baggage limit.

- **If missing:** Chaos—no control over how much data each user consumes.

9. NEF (Network Exposure Function):

- **What it is:** Allows external applications to communicate with 5G core securely.
- **Technical Role:** Exposes APIs to trusted applications (AFs).
- **Analogy:** The helpdesk where apps like Uber or PayTM can ask, "Where is the user?" or "Is the network congested?"
- **If missing:** Apps can't offer intelligent services based on network condition.

10. NRF (Network Repository Function):

- **What it is**: Registry of all active 5G functions.
- **Technical Role**: Tells AMF/SMF/others where to find other services dynamically.
- **Analogy**: A directory showing where immigration, baggage, or helpdesk is.
- **If missing**: None of the departments know how to find or talk to each other.

11. NSSF (Network Slice Selection Function):

- **What it is:** Chooses the correct network slice for each service or user.
- **Technical Role:** Maps a user to a slice (e.g., gaming slice, IoT slice).
- **Analogy:** Someone assigning you to a specific airline or flight based on your ticket type.
- **If missing:** Everyone crowded into the same flight—no speed or priority optimization.

12. SMSF (SMS Function):

- **What it is:** Enables SMS services over 5G Core.
- **Technical Role:** Lets UEs send and receive SMS using NAS or IMS.
- **Analogy:** Like sending postcards or urgent messages while inside the airport.
- **If missing:** SMS won't work natively in 5G SA.

13. AF (Application Function):

- **What it is:** App-level service logic interacting with PCF to request QoS.
- **Technical Role:** Provides input to PCF based on app needs (e.g., low latency for gaming).
- **Analogy:** You telling the airline "I need assistance for a medical condition" — they prioritize you.
- **If missing:** Apps can't dynamically request network preferences.

14. DN (Data Network):

- **What it is:** The final service network—Internet, IMS, Cloud, etc.
- **Technical Role:** Destination for user data.
- **Analogy:** The city or country you're flying to.
- **If missing:** No useful data services—only signaling would work.

End-to-End step by step flow: -

1. **User Equipment (UE)** like your phone wants to access the internet.
2. It connects to the **gNB (5G tower)**.
3. The gNB talks to the **AMF** to authenticate and manage mobility.
4. Then the **SMF** creates and manages sessions.
5. **UPF** handles the data traffic.
6. Meanwhile, other functions like **UDM**, **AUSF**, **NRF**, and **PCF** support the process.
7. Data finally reaches the **DN (Internet)**.