4. 5G Mobile Communication System User Guide

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Chapter 1: Introduction

1.1 Purpose and Intended Audience

1.1.1 Purpose

The purpose of this guide is to enable efficient and effective construction, management, and troubleshooting of the latest high-performance and feature-rich 5G MCS (Mobile Communication Systems). It is specifically intended for system designers and developers working with the entire system, including UE, gNB, and 5GC.
This guide provides the following:

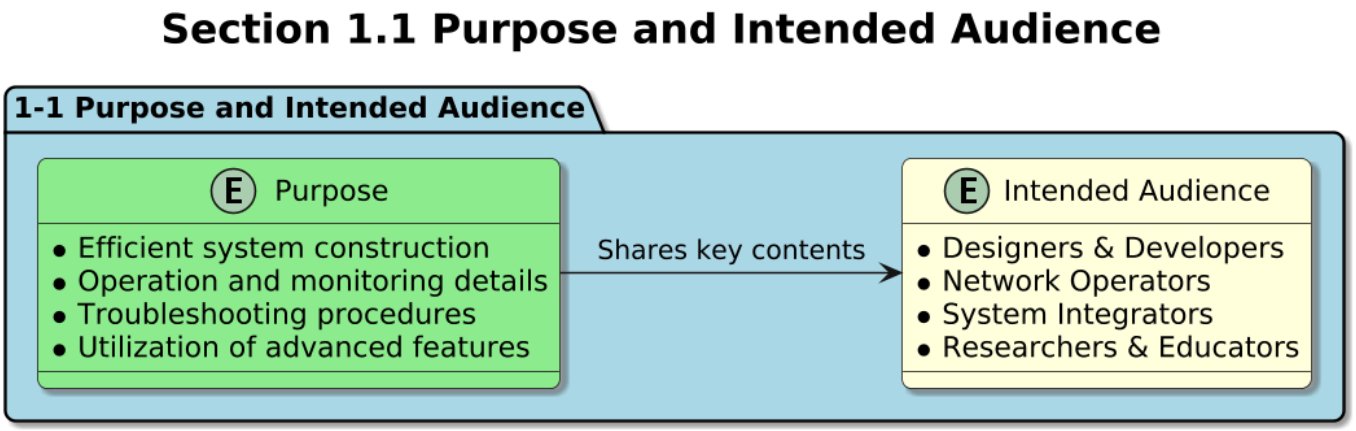
- Detailed explanation of the roles and configuration methods of each component
- Best practices for efficient system operation, management, and monitoring
- Step-by-step troubleshooting procedures in case of issues
- Guidelines for maximizing the use of advanced functionalities

1.1.2 Intended Audience

This guide is primarily intended for the following individuals:

- Designers and developers of 5G MCS
- Engineers responsible for end-to-end network architecture and deployment
- Network administrators and operators
- Personnel in charge of system operation, monitoring, and performance optimization
- System integrators
- Engineers involved in integrating 5G networks with other systems or services
- Researchers and educators engaged in applied 5G technology research or education

Below is a visual representation of the structure of this section:



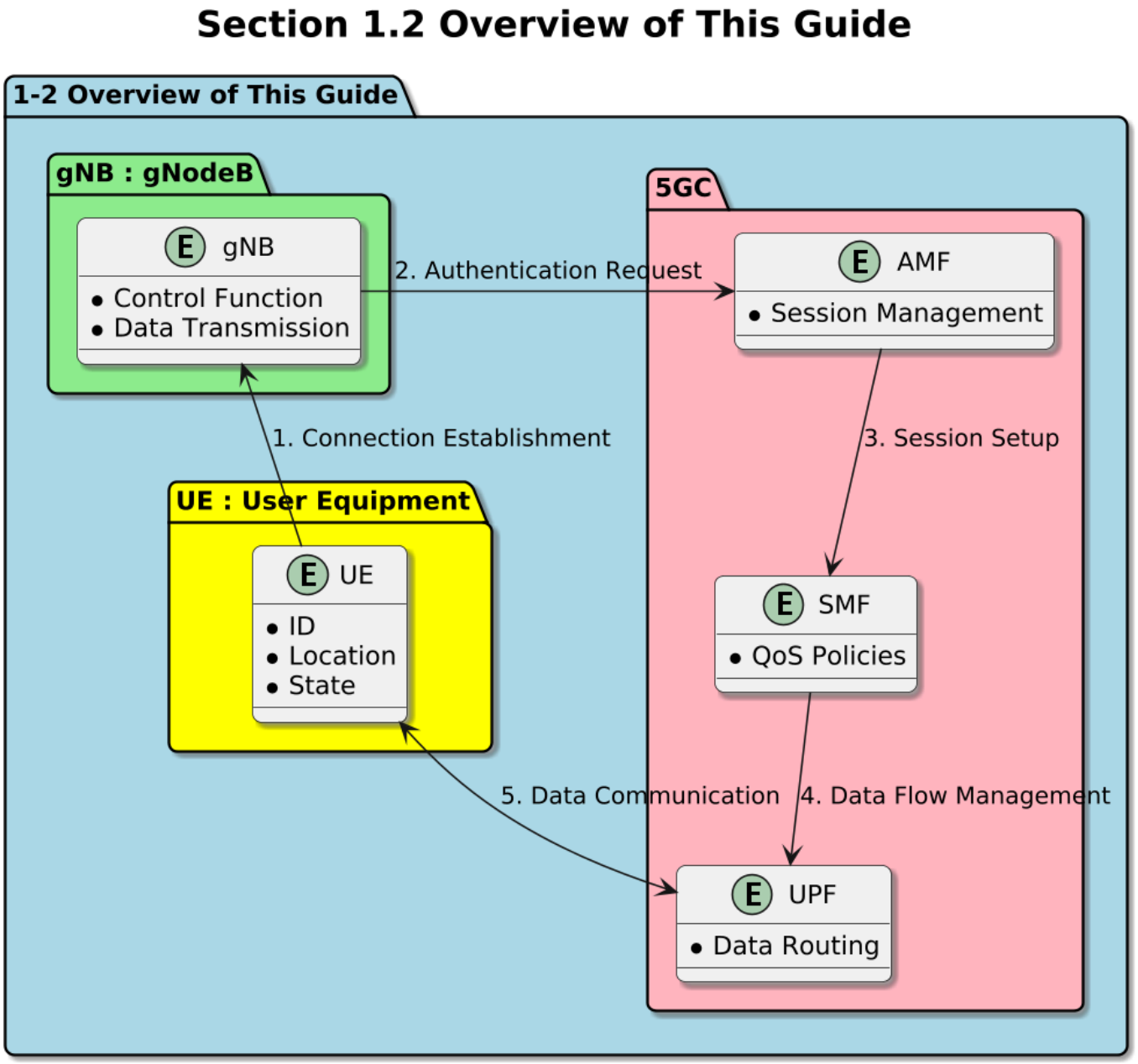
This diagram visually represents the purpose of this guide and its intended audience.

1.2 Overview of This Guide

This guide provides a detailed explanation of the basic architecture and usage of a 5G Mobile Communication System (MCS). It focuses on the following key points to help developers efficiently carry out actual implementation tasks:

- **Understanding the system architecture and functionality:**
  Explains how each component—UE, gNB, and 5GC—interacts and operates within the system.
- **Setup procedures:**
  Provides concrete installation and configuration steps to meet hardware and software requirements.
- **Operation and management:**
  Introduces tools and methods for monitoring and optimizing the network.
- **Troubleshooting:**
  Describes step-by-step methods for diagnosing and resolving common issues.
- **Advanced applications:**
  Covers use cases and advanced configurations that leverage the latest 5G technologies.

The diagram below illustrates the overall structure of a 5G MCS. It visually represents the relationships and data flows between the main components:



This diagram represents the basic data flow between major components in a 5G MCS and serves as a foundation for understanding their respective roles. Throughout this guide, we will explain in sequence how these components work together to form a fully functional system.

1.3 Prerequisites and Preparation

1.3.1 Prerequisites

Hardware Requirements

- UE (User Equipment): 5G-capable device
  - Required specs: 5G NR (New Radio) compatible modem, SIM card
- gNB (gNodeB): Supports 5G NR frequency bands
  - Required specs: Sub-6 GHz and mmWave support
- 5GC (5G Core): Software and hardware environment
  - Required specs: Server hardware or virtualized environment

Software Requirements

- Operating System
  - UE: RTOS or Android/Linux
  - gNB/5GC: Linux distributions (e.g., Ubuntu, CentOS)
- Required Software
  - 5GC: AMF, SMF, UPF modules
  - Network management tools

Environmental Requirements

- Network Connectivity: Internet and local network access
- Power Supply: Stable power source
- Physical Environment: Room temperature, low humidity

1.3.2 Preparation Steps

Step 1: Hardware Setup

- Prepare UE:
  Insert required modem and SIM card
- Install gNB:
  Ensure proper antenna placement and physical connections
- Set up 5GC Server:
  Connect necessary cables and perform initialization

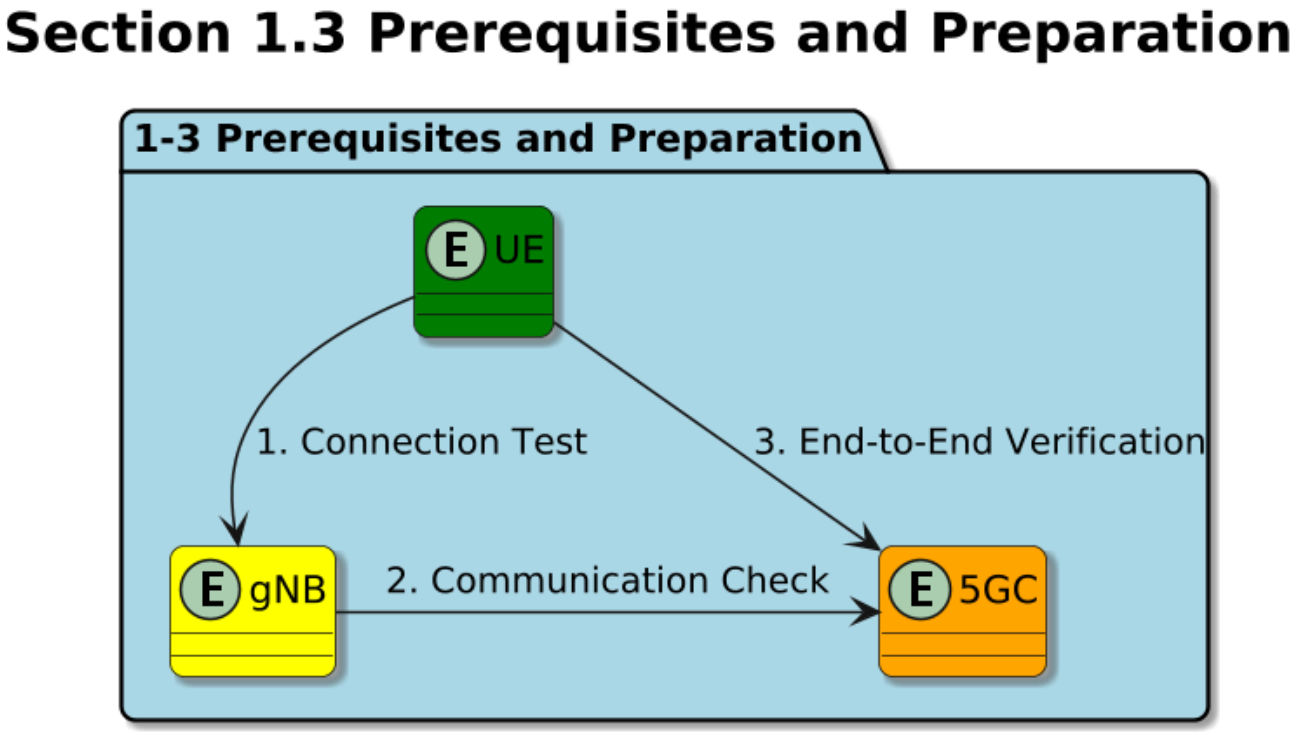
Step 2: Software Installation

- Install OS:
  Deploy the recommended OS on all components
- Install 5GC Modules:
  Set up AMF, SMF, UPF
- Set up Network Management Tools:
  Install monitoring and log analysis tools

Step 3: Network Verification

- Assign IP Addresses:
  Configure static IPs for all components
- Connectivity Test:
  Verify communication between UE, gNB, and 5GC

1.3.3 Diagram



This section outlines all necessary prerequisites and preparation steps to ensure the system is properly set up before operation.

Chapter 2: Overview of 5G MCS

2.1 Basic Architecture of a 5G Network

A 5G MCS (Mobile Communication System) consists of the following three main components. These components work together to deliver the key features of 5G, such as high-speed communication, low latency, and massive connectivity.

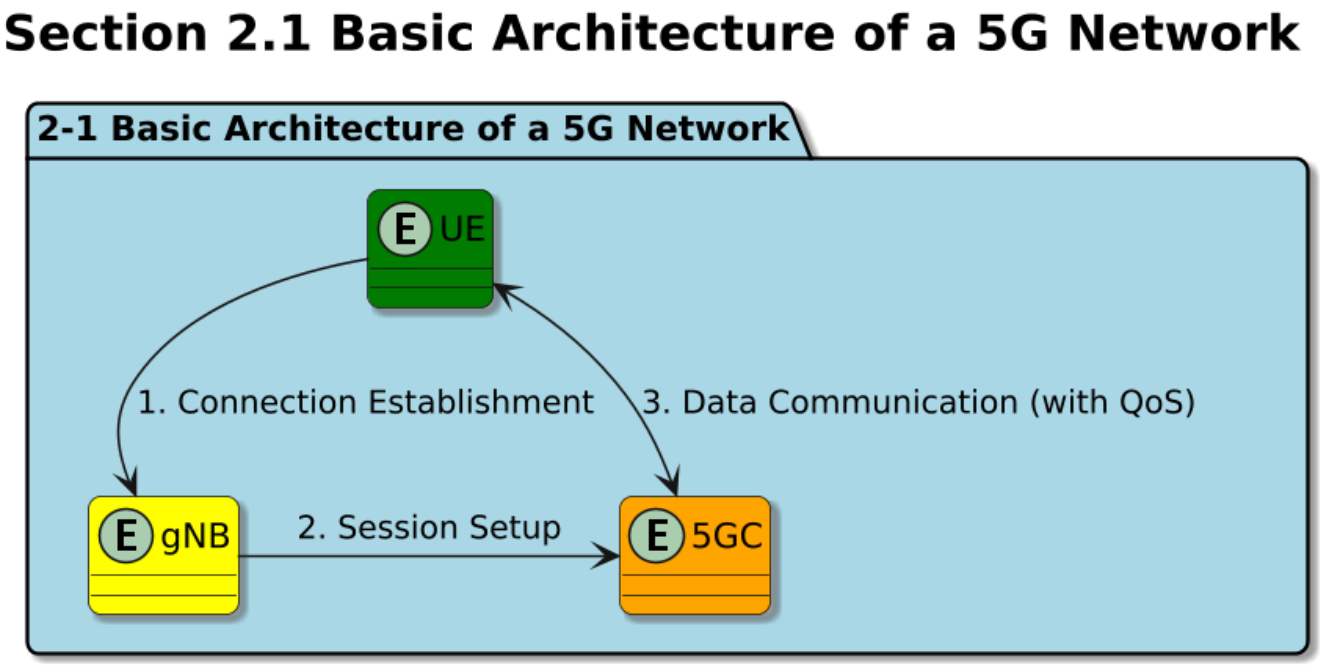
2.2.1 Core Components

1. **UE (User Equipment)**
    - Devices used by end users.
    - Examples include smartphones, IoT devices, and in-vehicle systems.
    - Equipped with a 5G-compatible modem for communication with the gNB.
2. **gNB (gNodeB)**
    - Functions as a base station and connects the UE to the 5GC.
    - Equipped with high-performance antennas and protocols to optimize data transmission.
3. **5GC (5G Core)**
    - The central system of the network.
    - Consists of modules such as AMF, SMF, and UPF, responsible for network management and control.

2.2.2 Basic Flow of the 5G Network

- The UE connects to the gNB.
- The gNB communicates with the 5GC to establish a session.
- Data transmission is optimized based on Network Slicing and QoS configurations.

2.2.3 Diagram



This section explained the overall structure of a 5G network and the roles of its main components. This provides the fundamental knowledge required for network design and operation.

2.2 Roles and Functions of Key Components (UE, gNB, 5GC)

2.2.1 Overview

A 5G network is composed of three key components: UE, gNB, and 5GC. Each plays a critical role in enabling the performance and flexibility of 5G. This section provides a detailed explanation of the roles and primary functions of each component.

2.2.2 Roles and Functions of Each Component

1. UE (User Equipment)

- Role:
  Acts as the device directly used by end users to communicate with the network.
  Examples:
  Smartphones, IoT devices, AR/VR headsets.
- Key Functions:
  - Connects to the gNB via the radio interface
  - Sends and receives data (voice, video, IoT data, etc.)
  - Establishes secure communication through authentication and encryption

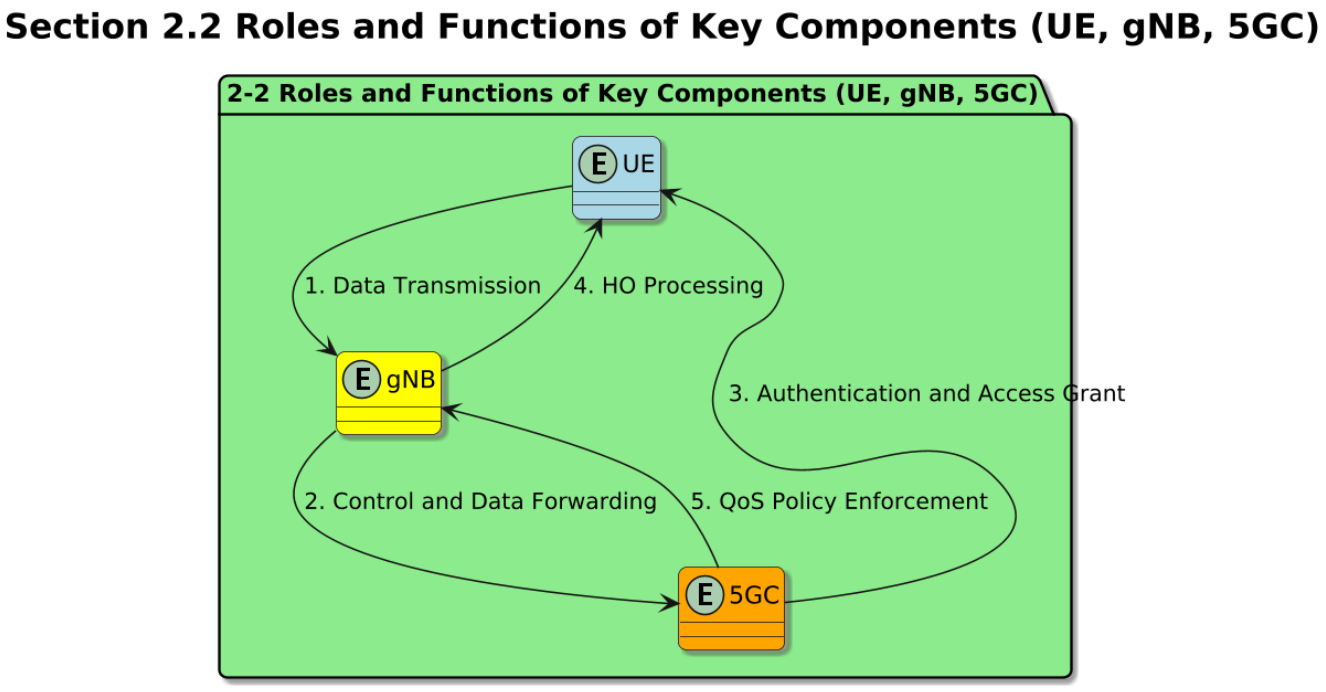
2. gNB (gNodeB)

- Role:
  Serves as a relay between the UE and the 5GC, forming the Radio Access Network (RAN).
- Key Functions:
  - Allocates and manages radio resources
  - Handles handover (HO) processes to optimize UE communication
  - Enforces Quality of Service (QoS) policies

3. 5GC (5G Core)

- Role:
  Controls and manages the entire 5G network, and handles data routing.
- Key Functions:
  - AMF: Manages user mobility
  - SMF: Establishes and controls sessions
  - UPF: Processes and forwards data traffic
  - Supports security management and user authentication

2.2.3 Diagram



This section clarified the roles and functions of each component and illustrated the overall flow of the network. It provides a foundational understanding of how a 5G network operates.

2.3 Features and Benefits of 5G

2.3.1 Key Features of 5G

High-Speed Communication

- Data Transfer Rate:
  5G can provide download speeds of up to 20 Gbps.
- Low Response Time:
  Communication latency is less than 1 ms, enabling real-time applications.

High Capacity

- Massive Device Connectivity:
  Supports up to 1 million connected devices per square kilometer.
- Efficient Bandwidth Usage:
  Utilizes radio frequencies with high spectral efficiency.

Low Latency

- Integration with Edge Computing:
  Reduces latency through local data processing.
- Real-Time Applications:
  Enables remote control, AR/VR, and vehicle-to-everything (V2X) communication.

Flexibility

- Network Slicing:
  Allows customized virtual networks tailored for specific use cases and industries.
- Programmability:
  Supports Software-Defined Networking (SDN) and Network Function Virtualization (NFV).

2.3.2 Benefits of 5G

Expansion of Industrial Applications

- Smart Factories:
  Improves efficiency through IoT devices and sensors.
- Remote Healthcare:
  Enables low-latency, high-quality video streaming for telemedicine.

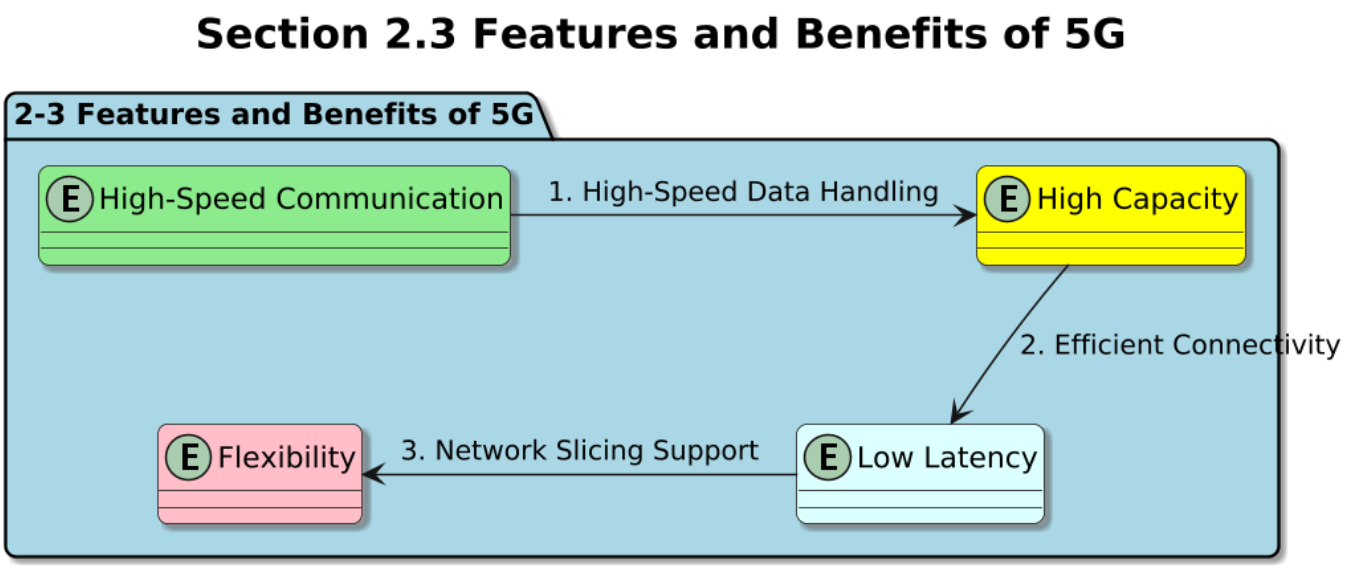
Enhancement of Everyday Life

- Entertainment:
  Supports 4K/8K streaming and immersive AR/VR experiences.
- Smart Cities:
  Facilitates environmental monitoring, traffic control, and energy optimization.

Economic Advantages

- New Business Models:
  Empowers innovative services over 5G networks.
- Infrastructure Efficiency:
  Optimizes capital investment in network facilities.

2.3.3 Diagram



This section outlined the unique features of 5G and the benefits they bring to both industry and daily life.

Chapter 3: HW and SW Setup

3.1 Required Hardware and Software Specifications

3.1.1 Hardware Requirements

UE (User Equipment)

- Processor:
  High-performance multi-core processor (e.g., ARM Cortex-A series)
- Memory:
  Minimum 4GB RAM
- Storage:
  At least 64GB of internal storage
- Communication Module:
  5G-compatible modem (supporting both Sub-6 GHz and mmWave)
- Power Supply:
  Stable battery or external power source

gNB (Next-Generation NodeB)

- Processor:
  Server-grade processor (e.g., Intel Xeon or AMD EPYC)
- Memory:
  Minimum 16GB RAM
- Storage:
  SSD with at least 500GB capacity
- Antenna:
  Massive MIMO-compatible antenna
- Power Supply:
  UPS backup is recommended

5GC (5G Core Network)

- Processor:
  High-performance server (AI-optimized with NVIDIA GPU, if applicable)
- Memory:
  Minimum 32GB RAM
- Storage:
  At least 1TB HDD/SSD with RAID configuration
- Network Interface:
  Ethernet port with 10Gbps or higher throughput
- Power Supply:
  Redundant power supply system

3.1.2 Software Requirements

UE

- OS: RTOS (e.g., FreeRTOS) or lightweight Linux distribution
- Protocol Stack: 5G protocol stack compliant with 3GPP standards
- Debug Tools: Firmware update and diagnostic software

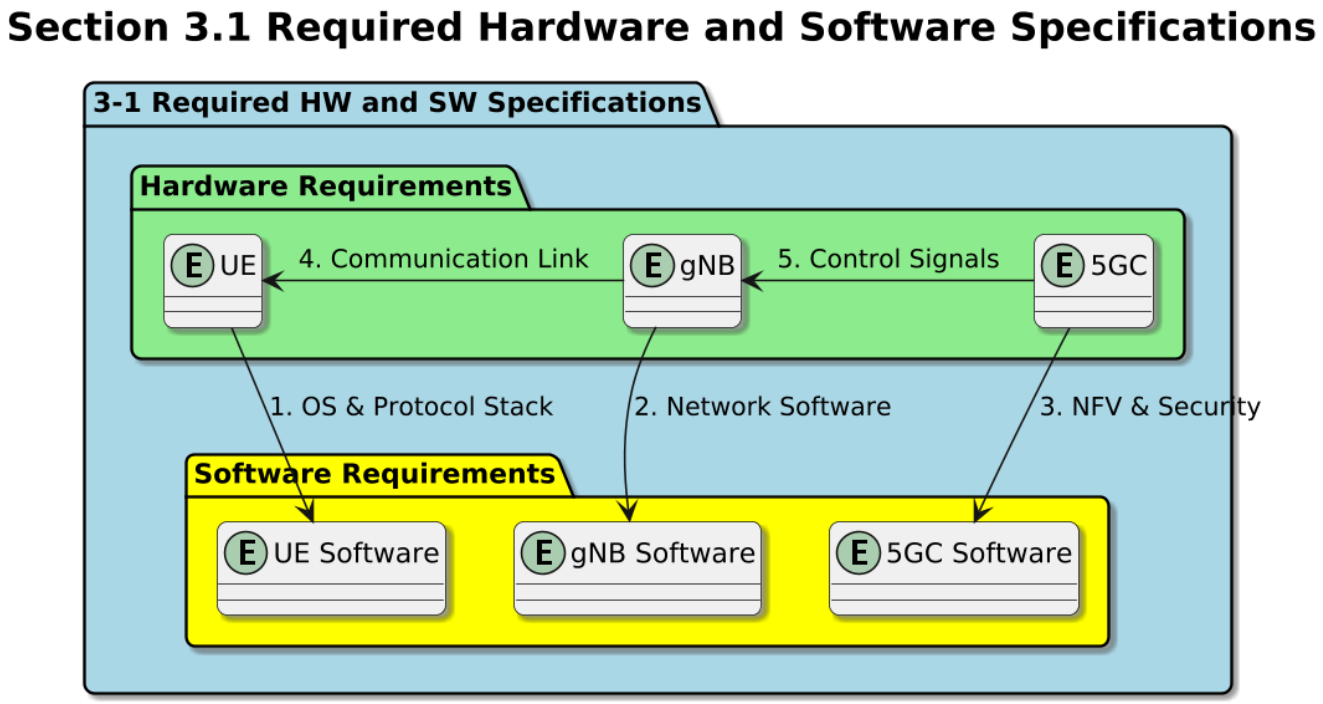
gNB

- OS: Linux-based (e.g., Ubuntu Server 20.04)
- Network Software: O-RAN-compliant software stack
- Management Tools: Remote management and monitoring utilities

5GC

- Virtualization Platform: Kubernetes or OpenStack
- NFV Solutions: Includes AMF, SMF, and UPF modules
- Security Solutions: Encryption and authentication services (supports TLS 1.3)

3.1.3 Diagram



This section defines the essential hardware and software requirements for building a 5G network, enabling a smooth setup process.