5G NR Layer-2 PDU Structure Definitions

A 3GPP-Compliant C Implementation

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***Abstract*—Fifth Generation New Radio (5G NR) introduces a flexible and service-oriented protocol architecture to support enhanced Mobile Broadband (eMBB), Ultra-Reliable Low-Latency Communications (URLLC), and massive Machine-Type Communications (mMTC). Layer-2 protocols play a critical role in ensuring reliability, quality of service, and efficient radio resource utilization.**

This paper presents a comprehensive and bit-accurate implementation of 5G NR Layer-2 Protocol Data Unit (PDU) header structures using the C programming language, strictly adhering to 3GPP Release 15 and Release 16 specifications. The implementation covers SDAP, PDCP, RLC, and MAC layers and is intended for academic learning, protocol understanding, and research prototyping.

***Index Terms*—5G NR, Layer-2, SDAP, PDCP, RLC, MAC, PDU, 3GPP, C Programming**

I. Introduction

5G New Radio (NR) represents a major evolution in cellular communication systems, designed to meet diverse performance requirements such as high throughput, ultra-low latency, and massive device connectivity. These capabilities are enabled by a modular protocol stack defined by the 3rd Generation Partnership Project (3GPP).

Layer-2 of the 5G NR protocol stack is responsible for data adaptation, security, reliability, segmentation, reordering, and multiplexing. Although the 3GPP specifications describe these protocols in detail, their PDU formats are complex and difficult to interpret directly. This project bridges the gap between specification and implementation by translating Layer-2 PDU definitions into precise C structures.

II. Motivation

Understanding real-world protocol behavior requires more than theoretical knowledge. Students and early-stage engineers often struggle to visualize how PDUs are structured at the bit level. This project was motivated by the need for:

- A clear mapping between 3GPP diagrams and actual code
- A reusable reference for protocol stack learning
- Interview and placement-oriented preparation for telecom roles

III. 5G NR Layer-2 Protocol Stack

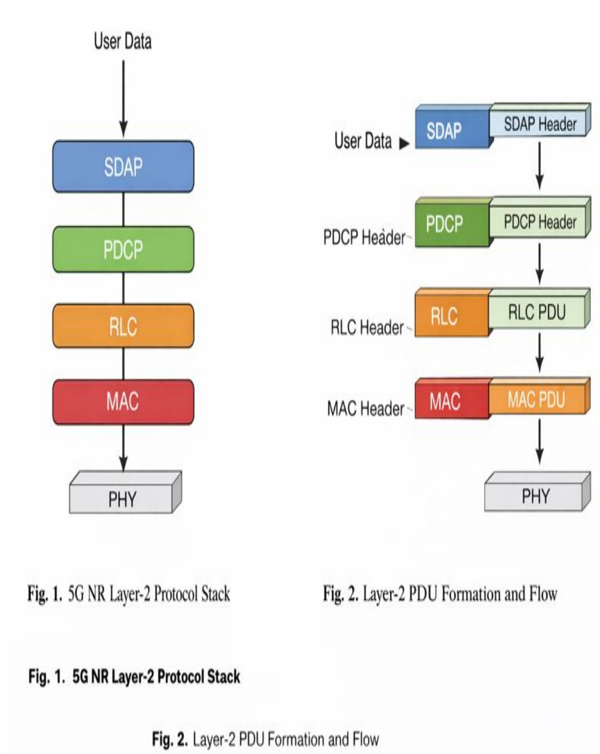

Fig. 1. 5G NR Layer-2 Protocol Stack

The 5G NR Layer-2 stack consists of four primary protocols:

- SDAP (Service Data Adaptation Protocol)
- PDCP (Packet Data Convergence Protocol)
- RLC (Radio Link Control)
- MAC (Medium Access Control)

Each protocol performs a distinct function and adds its own PDU header before passing data to the lower layer.

IV. Layer-2 PDU Processing Flow

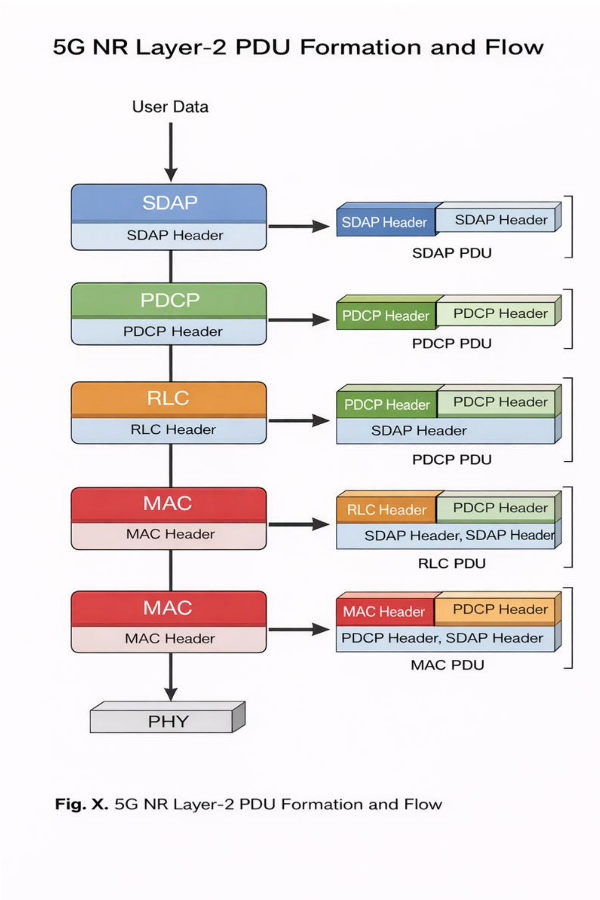

Fig. 2. Layer-2 PDU Formation and Flow

User data enters the Layer-2 stack at the SDAP layer and is progressively encapsulated with protocol-specific headers before transmission over the physical layer.

V. SDAP PDU Design

SDAP maps QoS flows to Data Radio Bearers (DRBs). The implemented SDAP PDUs include:

- SDAP Data PDU with Reflective QoS Indicator (RQI) and Reflective DRB Indicator (RDI)
- SDAP Data PDU without RQI and RDI

These PDUs are implemented using compact 1-byte headers, ensuring minimal overhead.

VI. PDCP PDU Design

PDCP provides security, header compression, and reordering. This project supports:

- PDCP Data PDUs with 12-bit and 18-bit sequence numbers
- PDCP Control PDUs for status reporting
- PDCP Control PDUs for ROHC feedback

Bit-fields are used to accurately represent PDCP header formats as shown in the specification.

VII. RLC PDU Design

RLC ensures segmentation, reassembly, and reliability. The following modes are implemented:

- Unacknowledged Mode (UM) – 6-bit and 12-bit SN
- Acknowledged Mode (AM) – 12-bit and 18-bit SN
- RLC AM STATUS PDUs

Segmented and complete PDUs are modeled separately for clarity.

VIII. MAC PDU Design

The MAC layer handles multiplexing, scheduling, and priority handling. Implemented MAC subheaders include:

- Short and long MAC subheaders
- Fixed-size MAC Control Element subheaders
- MAC subheaders with extension fields

These definitions closely follow TS 38.321.

IX. Implementation Methodology

All PDUs are implemented using C bit-fields. Multi-byte fields are reconstructed using:

$$SN = (SN_{high} \ll 8) | SN_{low} \tag{1}$$

Compiler dependency of bit-fields is documented as a limitation.

X. Testing and Output Verification

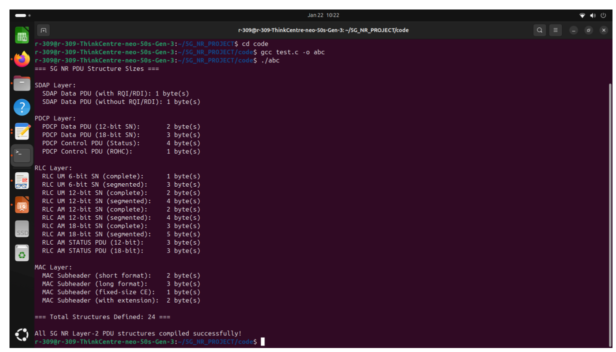

Fig. 3. Program Output Showing PDU Structure Sizes

A test program verifies the implementation by printing structure sizes using the `sizeof()` operator.

XI. Applications

- Academic learning and protocol visualization
- 5G protocol simulation
- SDR-based experimentation
- Telecom placement preparation

XII. Limitations

- Compiler-dependent bit-field layout
- No full packet encoding or decoding
- Not suitable for production systems

XIII. Future Enhancements

- Full encoder and decoder implementation
- Integration with GNU Radio and SDRs
- Support for future 3GPP releases

XIV. Conclusion

This paper presents a detailed and specification-compliant implementation of 5G NR Layer-2 PDU header structures in C. The project effectively bridges theoretical 3GPP documentation and practical implementation, making it valuable for students, researchers, and engineers.

References

[1] 3GPP TS 37.324, "Service Data Adaptation Protocol (SDAP) specification."

[2] 3GPP TS 38.323, "Packet Data Convergence Protocol (PDCP) specification."

[3] 3GPP TS 38.322, "Radio Link Control (RLC) protocol specification."

[4] 3GPP TS 38.321, "Medium Access Control (MAC) specification."