Mini Project Report

F1 Interface

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Abstract

The technological advancement of the modern world has enabled continuous connectivity and progress. A key enabler in this achievement is mobile technology.
5G has three major use cases : enhanced mobile broadband (eMBB), massive machine-type communication (mMTC), and ultra-reliable and low-latency communication (URLLC). The radio access interface of 5G called Next Generation Radio Access Network (NGRAN) has been re-designed keeping in mind the achievability of the use cases and at the same time has been designed to maintain backward compatibility with the legacy LTE Core Network, known as Evolved Packet Core (EPC).

In the design of NR, the splitting of sublayers plays a central role. Splitting gives the benefits of flexible hardware implementation, load management, and real-time performance optimization. Splitting opens doors for interfaces, One such interface due to gNB-CU and gNB-DU split is F1.

F1 Interface was studied and F1 Setup Procedures was implemented using socket programming in C.

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Abbreviations

NG-RAN :	Next Generation Radio Access Network
UE :	User Equipment
gNB-CU :	gNB-Central Unit
gNB-DU :	gNB-Distributed Unit
E-UTRAN :	Evolved – Universal Terrestrial Radio Access Network
F1-U :	F1 User plane
F1-C :	F1 Control plane
F1AP :	F1 Application Protocol
TNL :	Transport Network Layer
RNL :	Radio Network Layer
SCTP :	Stream Control Transmission Protocol
UPF :	User Plane Function
AMF :	Access and Mobility Management Function
E1 :	Interface between the data plane and the control plane

F1 Interface

1. Introduction

The F1 interface provides means for interconnecting a gNB-CU and a gNB-DU of a gNB within an NG-RAN, or for interconnecting a gNB-CU and a gNB-DU of an en-gNB within an E-UTRAN.[1]

Our goal was to understand F1 Interface procedures and implement F1-Setup Procedure according to specifications.

gNB internal structure is split into two parts called CU (Central Unit) and DU (Distributed Unit) . A gNB-CU and the gNB-DU units are connected via F1 logical interface. [1]

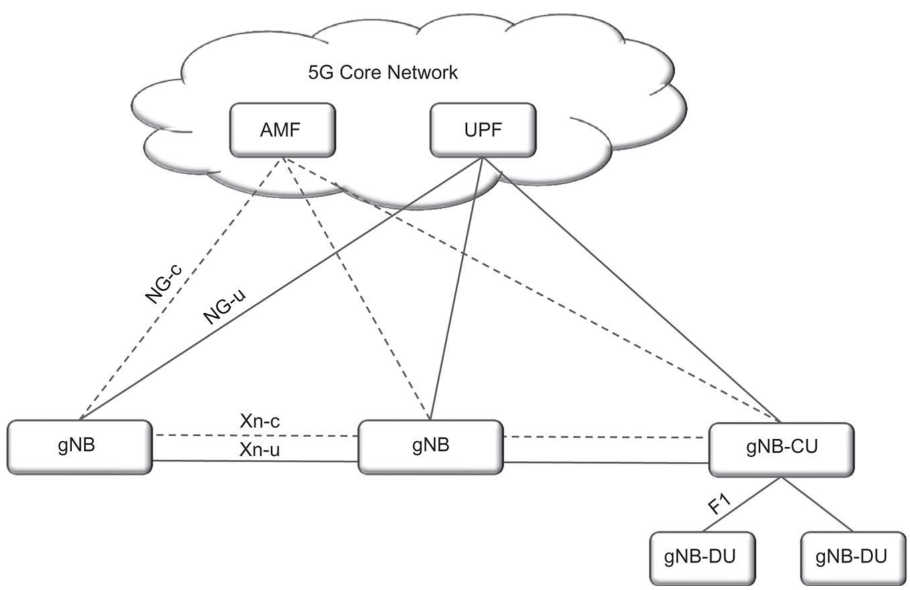
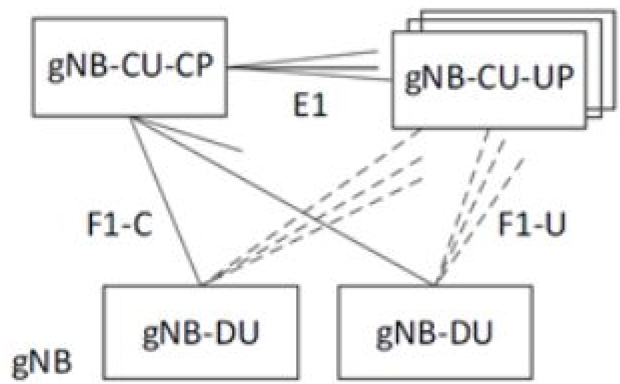


Fig 1: Radio Access Network Interfaces



The gNB CU consists of the RRC, SDAP and PDCP sublayers while the gNB DU consists of the RLC and MAC sublayers. The gNB CU is capable of handling multiple DU’s and hence the split architecture increases the efficiency of the design. The gNB DU is responsible for establishing a connection with the gNB CU by initiating the F1 setup procedure.

2. F1 Interface General Principles

The general principles for the specification of the F1 interface are as follows: [2]

- ❖ The F1 interface is open;
- ❖ The F1 interface supports the exchange of signalling information between the endpoints, in addition the interface supports data transmission to the respective endpoints;
- ❖ From a logical standpoint, the F1 is a point-to-point interface between the endpoints. NOTE: A point-to-point logical interface should be feasible even in the absence of a physical direct connection between the endpoints.
- ❖ The F1 interface supports control plane and user plane separation;
- ❖ The F1 interface separates Radio Network Layer and Transport Network Layer;
- ❖ The F1 interface enables exchange of UE associated information and non-UE associated information;
- ❖ The F1 interface is designed in a future proof way to fulfil different new requirements, support new services and new functions;

- ❖ One gNB-CU and a set of gNB-DUs are visible to other logical nodes as a gNB or an en-gNB where the gNB terminates the Xn and the NG interfaces, and the en-gNB terminates the X2 and the S1-U interfaces;
- ❖ The gNB-CU may be separated in control plane (CP) and user plane (UP)

3. F1 Procedures

Functionalities in F1 are split into F1-C and F1-U where F1-C consists of the procedures shown in the below figure.

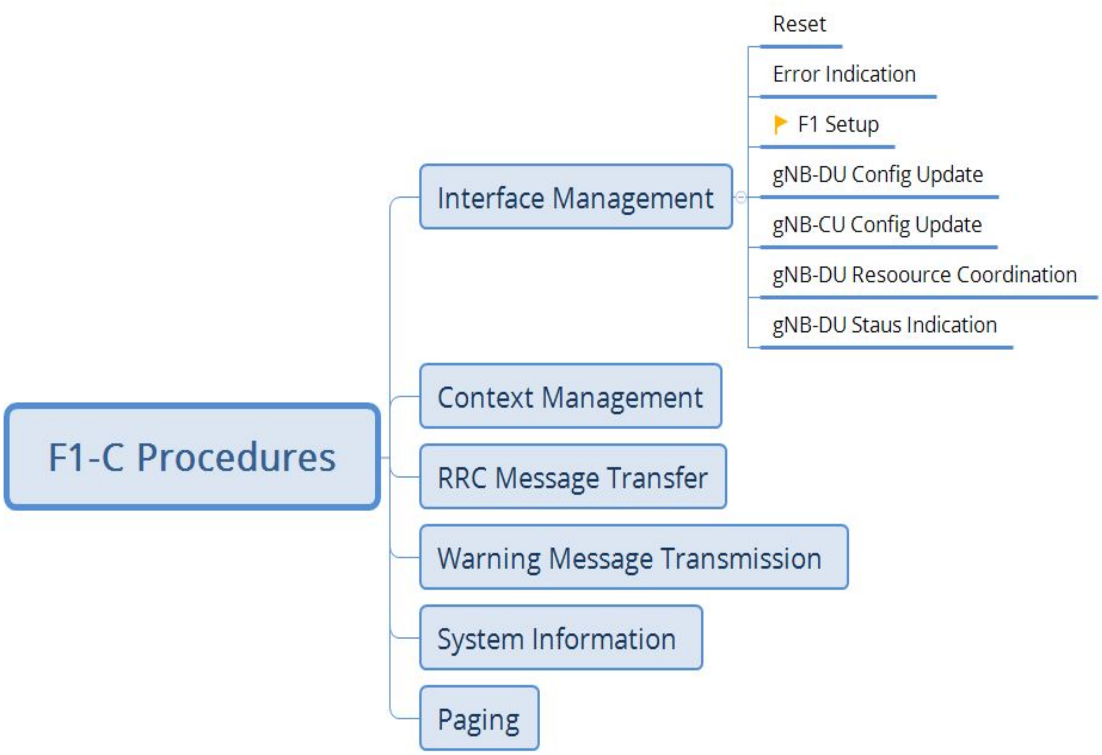


Fig 2 : F1-C Procedures

The below figure gives an overview of all F1 Procedures:

	Function	Overview
C-plane functions	Interface management	Interface setup, reset/configuration update, error indication
	System information management	Function for broadcasting system information
	UE context management	Function for UE context management
	RRC message transfer	Function for exchanging RRC signaling between gNB-CU and UE
	Paging	Function for operating paging for UEs
	Warning message information transfer	Function for transferring UE warning message (earthquake, tsunami, etc.)
U-plane functions	User data transfer	Transfer of user data between gNB-CU and gNB-DU
	Flow control	Flow control for gNB-DU

Fig 3: Functions of F1 [3]

4. F1 Setup Procedures

The F1 setup function allows to exchange application level data needed for the gNB-DU and gNB-CU to interoperate correctly on the F1 interface. The F1 setup is initiated by the gNB-DU.

F1 Setup can be successful or failure accordingly the procedures varies.

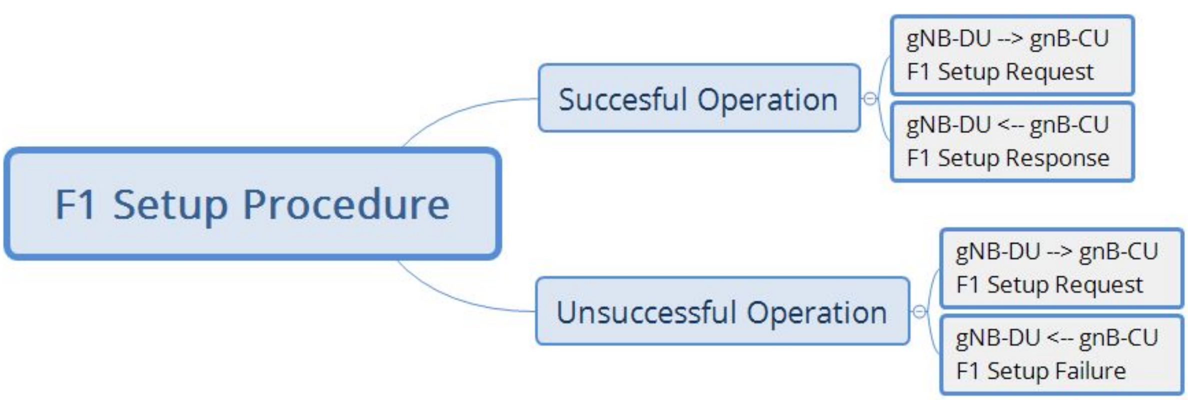


Fig 4: F1 Setup procedure

Successful Operation:

The gNB-DU initiates the procedure by sending a F1 SETUP REQUEST message including the appropriate data to the gNB-CU. The gNB-CU responds with a F1 SETUP RESPONSE message including the appropriate data.

The exchanged data shall be stored in respective node and used as long as there is an operational TNL association. When this procedure is finished, the F1 interface is operational and other F1 messages may be exchanged. [4]

Unsuccessful Operation:

If the gNB-CU cannot accept the setup, it should respond with a F1 SETUP FAILURE and appropriate cause value.

If the F1 SETUP FAILURE message includes the Time To Wait IE, the gNB-DU shall wait at least for the indicated time before reinitiating the F1 setup towards the same gNB-CU. [4]

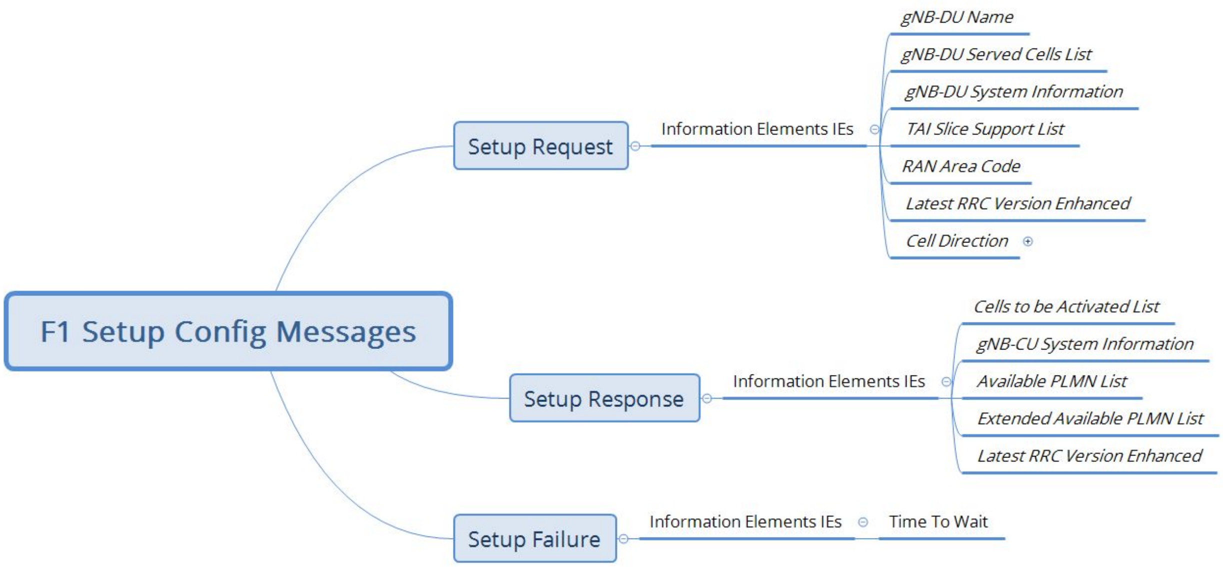


Fig 5: F1 Setup Config Messages

These config messages for F1 Setup Request, Response and Failure given in ASN.1 format are sent and received over the F1 Interface Protocol Structure.[4]

F1-Setup Request: gNB-DU → gNB-CU [4]

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Type	M		9.3.1.1		YES	reject
Transaction ID	M		9.3.1.23		YES	reject
gNB-DU ID	M		9.3.1.9		YES	reject
gNB-DU Name	O		PrintableString(SIZE(1..150,...))		YES	ignore
gNB-DU Served Cells List		*0.. 1*		List of cells configured in the gNB-DU	YES	reject
>gNB-DU Served Cells Item		*1.. <maxCellingNBDU>*			EACH	reject
>>Served Cell Information	M		9.3.1.10	Information about the cells configured in the gNB-DU	-	
>>gNB-DU System Information	O		9.3.1.18	RRC container with system information owned by gNB-DU	-	
gNB-DU RRC version	M		RRC version 9.3.1.70		YES	reject

Range bound	Explanation
maxCellingNBDU	Maximum no. cells that can be served by a gNB-DU. Value is 512.

F1 Setup Response: gNB-CU → gNB-DU [4]

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Type	M		9.3.1.1		YES	reject
Transaction ID	M		9.3.1.23		YES	reject
gNB-CU Name	O		PrintableString (SIZE(1..150,...))	Human readable name of the gNB-CU.	YES	ignore
Cells to be Activated List		*0.. 1*			YES	reject
>Cells to be Activated List Item		*1.. <maxCellingNBDU>*		List of cells to be activated	EACH	reject
>> NR CGI	M		9.3.1.12		-	
>> NR PCI	O		INTEGER (0..1007)	Physical Cell ID	-	
>>gNB-CU System Information	O		9.3.1.42	RRC container with system information owned by gNB-CU	YES	reject
>>Available PLMN List	O		9.3.1.65		YES	ignore
>>Extended Available PLMN List	O		9.3.1.76	This is included if *Available PLMN List* IE is included and if more than 6 Available PLMNs is to be signalled.	YES	ignore
gNB-CU RRC version	M		RRC version 9.3.1.70		YES	reject

Range bound	Explanation
maxCellingNBDU	Maximum no. cells that can be served by a gNB-DU. Value is 512.

F1 Setup Failure: gNB-CU → gNB-DU [4]

Direction: gNB-CU → gNB-DU

IE/Group Name	Presence	Range	IE type and reference	Semantics description	Criticality	Assigned Criticality
Message Type	M		9.3.1.1		YES	reject
Transaction ID	M		9.3.1.23		YES	reject
Cause	M		9.3.1.2		YES	ignore
Time to wait	O		9.3.1.13		YES	ignore
Criticality Diagnostics	O		9.3.1.3		YES	ignore

5. F1-C interface protocol structure

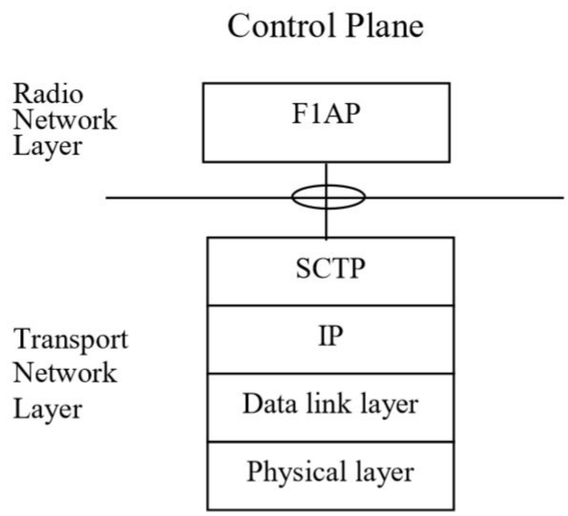


Fig 4 : Interface Protocol Structure of F1-C

Transport Network Layer:

The TNL is based on IP transport, comprising the SCTP on top of IP. It is responsible for the transfer of the transfer of the protocol elements across the Transport network.

Radio Network Layer

The application layer signalling protocol is referred to as F1AP (F1 Application Protocol). This protocol runs on top of the TNL and is the interface between the TNL and 5G L2 Protocols.

6. SCTP

SCTP refers to the Stream Control Transmission Protocol developed by the Sigtran working group of the IETF for the purpose of transporting various signalling protocols over IP network

SCTP is a standard protocol (RFC 2960) developed by the Internet Engineering Task Force.

The SCTP Destination Port number value assigned by IANA to be used for F1AP is 38472 and the Payload Protocol Identifier is 62.

TCP transmits data in a single stream guarantees that data will be delivered in sequence to the application or user at the end point. If there is data loss, or a sequencing error, delivery must be delayed until lost data is retransmitted or an out-of-sequence message is received.

SCTP's multi-streaming allows data to be delivered in multiple, independent streams, so that if there is data loss in one stream, delivery will not be affected for the other streams. For some transmissions, such as a file or record, sequence preservation is essential. However, for some applications, it is not absolutely necessary to preserve the precise sequence of data. For example, in signaling transmissions, sequence preservation is only necessary for messages that affect the same resource (such as the same channel or call). Because multi-streaming allows data in error-free streams to continue delivery when one stream has an error, the entire transmission is not delayed.

7. ASN Encoding and Decoding

Abstract Syntax Notation (ASN.1) is the standard to define specifications of abstract data types. It is also used in 3GPP documents. The main reason to use ASN.1 is it is easy to convert the ASN.1 to any other language.

ASN.1 sends information(audio,data,etc) in digital communication. It only covers the structural aspects of the information(there are no operators). Therefore it is not a programming language. We can convert the ASN.1 language to other languages like C,C++ or Java by using the respective compiler.

In ASN.1 there are a certain number of predefined data types like :

- integers (INTEGER),
- boolean (BOOLEAN),
- character strings (IA5String, UniversalString...)
- bit strings (BIT STRING) and etc.

It is possible to define constructed types such as :

- structures (SEQUENCE),
- lists (SEQUENCE OF),
- choice between types (CHOICE)

The important part of ASN.1 notation is that it is associated with several standardized encoding rules , which can be used in case of bandwidth restriction. ASN.1 is widely used in industry sectors where efficient (low-bandwidth, low-transaction, low-cost) computer communications are needed, but is also being used in sectors where XML- encoded data is required (for example, transfer of biometric information).

Source Code:

We worked on F1-Setup procedures to setup the interface between gNB-CU and gNB-DU. The source code can be accessed through the drive link mentioned below. Readme file is provided for running the code.

https://drive.google.com/open?id=129qEieUhBF2EFCxPb-S0FNVy1tQYpJdl.

Conclusions and Extensions:

1. The F1 Setup Procedures were implemented after the understanding of F1-AP protocol standards, SCTP Protocol standards and ASN Encoding and Decoding algorithms.

2. Support for further F1 procedures will be added according to the 3gpp standards.

3. F1 AP is a part of the L2 control plane stack and is required for the integration of all the sublayers.

Bibliography:

[1] Dahlman, E., Parkvall, S. and Skold, J., 2018. *5G NR: The next generation wireless access technology*. Academic Press.

[2] F1 general aspects and principles (3GPP TS 38.470 version 15.6.0 Release 15)

[3] “5G NR Interfaces X2/Xn, S1/NG, F1 and E1 Functions” May. 24, 2019 [Online]. Available: http://www.techplayon.com/5g-nr-interfaces-x2-xn-s1-ng-f1-and-e1-functions/

[4] F1 Application Protocol (F1AP) (3GPP TS 38.473 version 15.7.0 Release 15)