

5G NR based initial access procedure simulation environment implementation including system information using ns-3 simulator

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Abstract— In mobile communications, the RRC layer protocol defines a procedure for how a UE initially accesses a base station. In particular, information for cell access is required for initial access, and the UE can obtain such information through system information blocks such as MIB and SIB transmitted by the base station.

As the network evolves from LTE to 5g nr, the protocol of the RRC layer for initial access has also changed a lot. In LTE, it was necessary to access a cell through MIB, SIB1, and SIB2 information, but in 5g nr, since SIB1 also includes LTE's SIB2 information, it is possible to access a cell with only MIB and SIB1.

In this paper, we analyzed how the initial access procedure of 5g nr and the system information required for it are different compared to LTE. In addition, after analyzing the LTE-based RRC layer protocol provided by default through the current ns-3 simulation environment, the system information and RRC state transition process for 5g nr-based initial access were implemented with ns-3 code.

Then, through the implemented code, it was confirmed whether the UE was normally connected to the base station, and the performance was evaluated by checking what difference it has from LTE. Implementation of initial access process in 5g nr using ns-3 is expected to be an important cornerstone for implementing 5g nr based RRC layer protocol in the future.

Keywords— 5g NR, Initial access, ns-3 simulation, RRC protocol, System information blocks.

I. INTRODUCTION

3GPP started establishing 5G NR standards in 2016, and standard documents up to Rel.17 were finalized [1]. Among the 5G NR standards, TS 38.331, an RRC (Radio Resource Control) protocol standard, describes contents related to radio access between a UE and a BS. [2].

The RRC procedure includes processes such as initial access by the UE to the BS, establishment of an RRC Connection for connection between radio sections (or AS), and handover to provide mobility in a connected state.

Among them, the step of initial access to the BS includes a process of receiving system information blocks such as MIB (Master Information Block), SIB1 (System Information

Block1), and SIB2 (System Information Block2) after DL (Downlink) sync through SSB (Synchronization Signal Block). Here, MIB and SIB1 are transmitted as one message through the PBCH (Physical Broadcast Channel) and PDSCH (Physical Downlink Shared Channel), respectively, and SIB2 is included in a message called SI (System Information) and transmitted through the PDSCH. That is, the SIB2 block can be included in the SI message, but SIB3 or other SIBn blocks can also be included if necessary.

In LTE, since MIB, SIB1, and SIB2 contain information for accessing cells, they contain crucial information for the UE [3]. In particular, MIB contains information for receiving SIB1, SIB1 contains cell access information, and SIB2 contains RACH (Random Access Channel) information for Uplink synchronization in a cell. On the other hand, SIB1 in 5G NR includes information on cell access as well as RACH information and scheduling information on how other SI blocks beyond SIB2 are transmitted.

Therefore, while in LTE, all MIB, SIB1, and SIB2 had to be received in order for the UE to start the RACH process and transmit the RRC request message for RRC Connection to the network (BS), in 5G nr connection request can be initiated by receiving only MIB and SIB1.

Currently, ns-3 is a representative tool for 5G NR mobile communication network simulation [4]. In particular, in the 5G LENA project, Ns-3 provides some of the 5G NR functions up to the latest 3GPP standard Rel-15, enabling simulation based on more recent standards [5].

However, even in the 5G LENA project, the RRC layer reuses the RRC provided by the existing LTE, so RRC for the latest 5G NR cannot be used [6].

Therefore, in this paper, in order to reflect the changes in system information for RRC initial access as seen in Figure 1, the existing SIB1 and SIB2 messages provided by ns-3 and the connection process according to message reception were modified and applied.

Through performance evaluation using the Ns-3 simulation, it was found that the 5G NR-based RRC we implemented is able to achieve an RRC connected state more quickly than before.

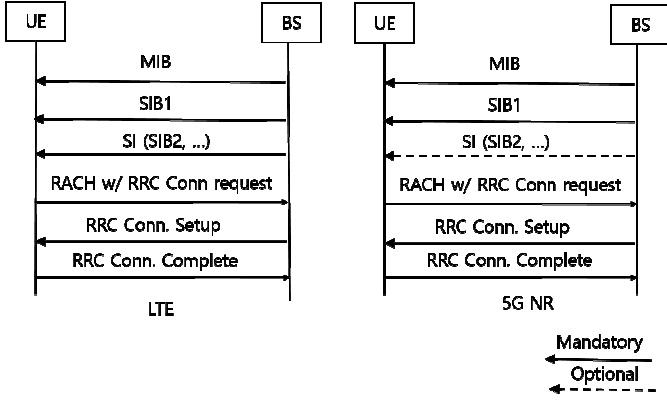


Figure 1. System Information sequence diagram in LTE and 5G NR

The structure of this paper is as follows. Section II explains how to implement 5G NR-based initial access using the existing ns-3 source code. Next, Section III evaluated the performance of the implemented ns-3 code, and finally, Section IV presents the conclusion.

II. 5G NR-BASED RRC IMPLEMENTATION USING NS-3

TABLE 1. MIB/SIB BLOCK IN LTE AND 5G NR

System Information	LTE	5G NR
MIB	System Frame Number, Ssb-SubcarrierOffset, cellBarred	System Frame Number, Ssb-SubcarrierOffset, cellBarred
SIB1	Cell Selection/Access Info	Cell Selection/Access Info, SI schedule, RACH ConfigGeneric
SIB2	RACH ConfigGeneric, Other info	Cell re-selection info. (Intra-freq/inter-freq/inter-RAT)

Table 1 shows how the contents of MIB and SIB blocks in the existing LTE-based RRC and the 5G NR-based RRC are different. MIB includes information for receiving SIB1 and both LTE and 5G nr include System Frame Number. In SIB1, there is only information for cell selection and access in the case of LTE, while in the case of 5G NR, information for cell selection and access, scheduling information of other SIBs including SIB2, and RACH information for cell and UL synchronization are included. Finally, SIB2 used to include RACH information in the case of LTE, but in the case of 5G NR, it contains information for cell re-selection.

Figure 2 shows the change of the RRC State of the UE during the initial access process in the ns-3 simulation.

First, in the case of LTE RRC-based initial access (a), the UE starts from IDLE, enters the cell search stage for cell access, and selects the cell with the best signal.

Then, it enters the state of waiting for the MIB and SIB1 messages from this cell, and changes to IDLE_WAIT_SIB1 when the MIB broadcast by the cell is received, and changes to IDLE_CAMPED_NORMALLY when SIB1 is received, so that it can now stay connected in this cell.

Then, when an access request comes from the upper layer of the UE, it waits for the SIB2 message and, when it receives it,

sets the RACH information in the SIB2 block to the UE and starts the RACH process.

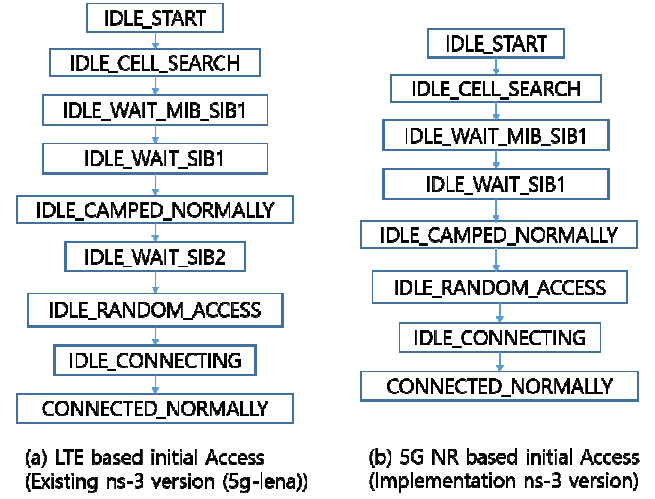


Figure 2. Initial access based on existing LTE and 5G NR RRC

At this time, the first message of the RACH becomes the Preamble RACH, and when a response is received from the cell to the RAR, an RRC connection request message is transmitted to the cell as the third message as Figure 1.

Afterwards, if the cell permits access, an RRC setup message is transmitted to permit the connection, and the UE sends an acknowledgment so that both the UE and the BS move to the CONNECTION state.

Next, in the case of 5G NR-based RRC (Figure 2b) implemented in this paper, when there is an access request from the upper layer of the UE, unlike LTE RRC, there is no need to wait for SIB2, as RACH information originally set through SIB1 is used and the RRC connection process can be continued.

III. PERFORMANCE EVALUATION

To find out how the 5G NR RRC-based initial cell access differs from the existing LTE RRC, we evaluated the performance using the ns-3 simulator.

In particular, in the case of the RRC layer of the latest version of ns-3, 5G LENA, the LTE version of RRC was used, so the initial cell access was performed through MIB, SIB1, and SIB2 messages.

Therefore, for comparison with the existing method, we implemented 5G NR RRC by modifying the method that operates in the current 5G NR standard to allow initial access so that cell access is possible even if only MIB and SIB1 messages are received.

In addition, in order to check the time taken for the UE to access the cell in the existing LTE RRC and 5G NR, MIB, SIB1, and the setting of the transmission cycle of SIB2 through the SI message were set identically as follows.

TABLE 2. NS-3 SYSTEM INFORMATION MESSAGES PERIOD SETTINGS

Parameter	Period (sec)
MIB	0.010 (initial : 0.010)
SIB1	0.010 (initial: 0.015)
SI (SIB2)	0.080 (initial: 0.040)

The network model was simulated by connecting one UE and one gNB and setting the environment to communicate with the 5g Core network.

TABLE 3. SIMULATION RESULTS (SEC)

UE RRC State	Existing LTE RRC (5G LENA) ns-3 code	Implemented 5G NR RRC ns-3 code
IDLE_START	0.000	0.000
IDLE_RANDOM_ACCESS	0.040	0.015
CONNECTED_NORMALLY	0.045	0.020

Table 3 shows the UE RRC State changing as the simulation time progresses. As expected, in the case of the existing LTE RRC, an access attempt is made through the RACH process only after SI (SIB2) is received, so the initial access can be completed at 0.045s. On the other hand, in the case of the 5G NR RRC code we implemented, it was confirmed that the initial connection can be made at 0.020s, which is faster than the LTE-based method, because a connection attempt can be made immediately when SIB1 is received.

IV. CONCLUSIONS

In the case of the ns-3 code of the existing 5G LENA, the latest standard was not reflected because the RRC layer reuses LTE RRC.

In this paper, the RRC-based initial access process defined in the latest 5G NR standard currently managed by 3GPP was implemented in ns-3.

Our implementation consists of moving the RACH information in the SIB2 message to SIB1 in the ns-3 code so that initial access can be made immediately even when only the SIB1 message is received.

As a result of the simulation, it was found that the initial connection can be made faster when using the proposed method compared to the existing LTE RRC.

In addition, since our implementation is a code that can put scheduling information of other SIB messages (other SIB blocks including SIB2) into the SIB1 message, this work may become a good foundation for future works based on the latest 5G NR RRC.

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