A Network Architecture of NOMA-CDRT based on 3GPP New Radio Standards

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***Abstract*—In this paper, a network architecture is introduced to enable the non-orthogonal multiple access in coordinate direct and relay transmission (NOMA-CDRT) protocol building upon existing standard specifications. The relay protocol in NOMA-CDRT is realized through the integrated access and backhaul (IAB) from the 3rd generation partnership project (3GPP). The radio access network (RAN) standards in the 3GPP new radio (NR) are considered to design the architecture of NOMA-CDRT. In particular, the network architecture and protocol stacks are introduced to implement the heterogeneous network (HetNet) features of NOMA-CDRT.**

***Index Terms*—Non-orthgonal multiple access, coordinated direct and relay transmission, network architecture, integrated access and backhaul.**

I. Introduction

In the future 6G network, the necessity to enhance coverage and elevate data transmission rates will drive the deployment of a more dense and complicated networks [1]–[3]. Because the 6G networks become dense and complicated, constructing backhaul links based on optic fiber can substantially raise implementation costs. Therefore, utilizing wireless links for the backhaul connection has been considered naturally to achieve cost-saving advantages. Furthermore, employing the self-backhauling technique will greatly enhance both cost and spectral efficiency.

Recently, non-orthogonal multiple access (NOMA) has been in the spotlight as one of the candidate technologies for the 6G mobile communication services [4], [5]. Using the method of breaking orthogonality and transmitting multiple user data superimposed on the same radio resource, NOMA can achieve not only high spectral efficiency but also accommodation of a significantly large number of users [6]. In addition, the expansion of NOMA into relay systems and/or heterogeneous network (HetNet) has been conducted in [7]–[9]. In the context of the dense and HetNet environments, NOMA in coordinated direct and relay transmission (NOMA-CDRT) was proposed and the spectral efficiency was doubled in high signal-to-noise-ratio (SNR) regimes [10]. By wisely combining NOMA and relay protocols to manage and exploit the interferences, NOMA-CDRT achieves rate gains in HetNet. However, the previous works were conducted based only on theoretical protocol and assumptions, but there was no consideration for implementing NOMA-CDRT based on existing standards.

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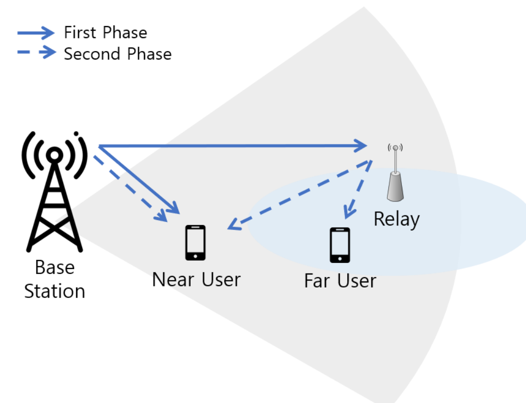


Fig. 1: System model of NOMA-CDRT consist of a near user, far user and relay.

In this paper, a network architecture is introduced to enable the NOMA-CDRT protocol building upon existing standard specifications. The relay protocol in NOMA-CDRT is realized through the integrated access and backhaul (IAB) from the 3rd generation partnership project (3GPP) [11]. The radio access network (RAN) standards in the 3GPP new radio (NR) are considered to design the architecture of NOMA-CDRT. In particular, the network architecture and protocol stacks are introduced to implement the HetNet features of NOMA-CDRT.

II. System Model

Fig. 1 illustrates the NOMA-CDRT in HetNet scenario, which involves two users and a relay node. The base station (BS) encompasses a macro cell that covers both the near user and the relay, while the far user is located within the coverage

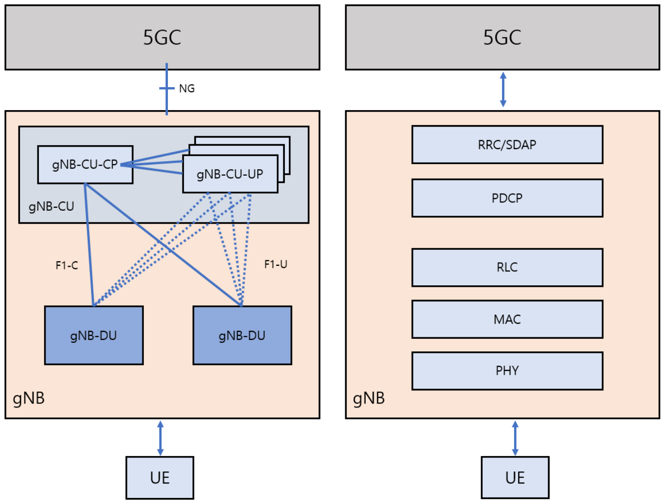


Fig. 2: NR standard CU/DU split and protocol stack.

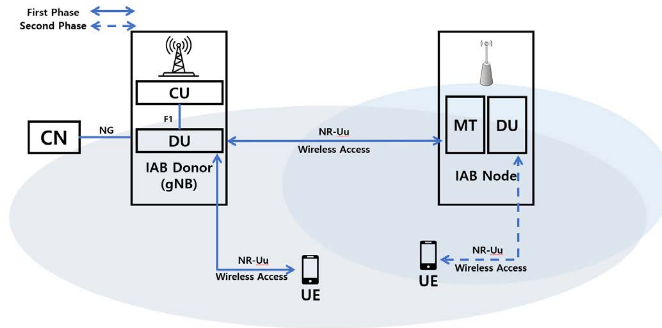


Fig. 3: NOMA-CDRT network architecture.

area of the relay's small cell. Within the macro cell, the BS provides the access link for the near user and employs the same wireless backhaul channel for the relay. The far user, positioned at a distance from the BS, establishes a connection to the small cell through a decode and forward relay, which may potentially result in interference to the near user.

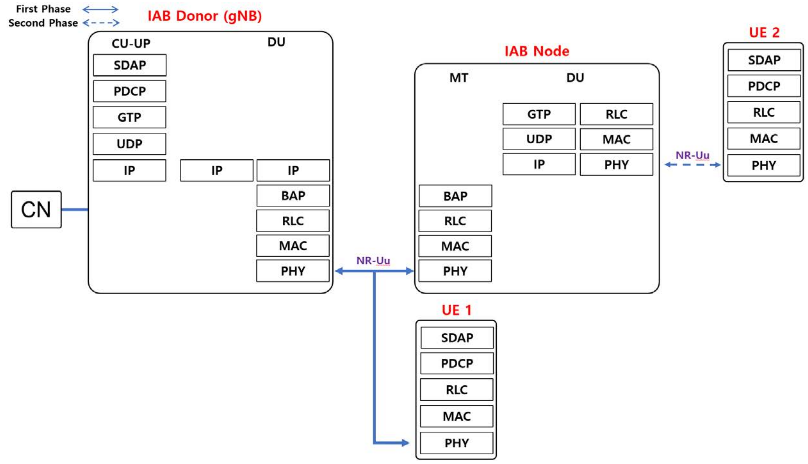
In NOMA-CDRT protocol, data transmission occurs in two phases using a half-duplex approach. The BS sends a superimposed signal containing both the near user's and the far user's signals simultaneously. Additionally, power allocation is employed to allocate less power to the near user signal and more power to the far user signal. During the first phase, the BS transmits the superimposed signal to both the near user and the relay. In the second phase, the BS transmits only the signal of the near user directly to the near user, while the relay forwards the signal of the far user to the far user. However, because the near user is within the relay's coverage, the signal from the distant user will be considered as interference. The near user first decodes the far user's signal using successive interference cancellation (SIC) and obtains its own signal. Note that the near user has both its and the far user's signal by using SIC. The far user was allocated more power in the superimposed signal, leading to power allocation differences and considering the near user's signal as interference at the relay due to the distance factor. During the second phase, the near user experienced unwanted interference from the far user's signal transmitted by the relay. However, the near user can cancel out this interference by utilizing the signal obtained through SIC during the first phase.

III. NOMA-CDRT Architecture Based on 3GPP New Radio Standards

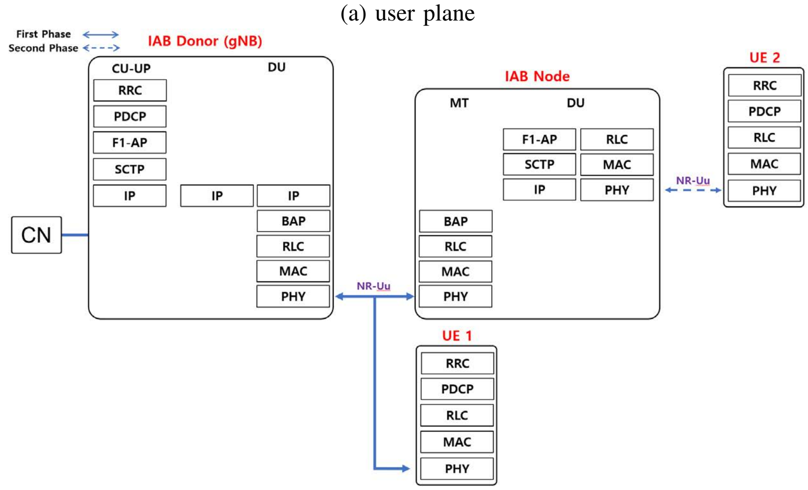
Fig. 2 shows the 3GPP separated the functionality of NR standard base station (gNB) into central unit (CU) and distributed unit (DU), CU includes packet data convergence protocol (PDCP), radio resource control (RRC) protocol and DU includes radio link control (RLC), medium access control (MAC) and physical layer [12]. CU connects the core network (CN) via NG interface and CU connects DU via F1 interface. Each gNB is consist of a CU and one or more DUs. This split achieves flexibility and efficient network architecture, enabling better resource management, scalability and performance. CU handles less time critical radio functionalities while DU handles time critical radio functionalities. CU consists of control plane (CP) and user plane (UP). CP processes various control signals to deliver user data well, and UP processes user data. CU-UP can connect to multiple DUs, but must be controlled by the same CU-CP.

The IAB network consists of an IAB donor and IAB node (one or more). IAB donor stands for gNB and IAB node is connected to donor. IAB node has mobile termination (MT) and DU part. The MT is connected to the DU of the donor, and the DU part may be connected directly to the user equipment (UE) or to other IAB nodes. From the UE's point of view, the DU of the IAB node is recognized as the DU of the gNB, and from the donor's point of view, the MT of the IAB node is recognized as the UE. The protocol structure of the IAB network is divided at the RLC layer, and the backhaul adaptation protocol (BAP), which is responsible for routing and RLC channel mapping for multi-hop-based relay transmission, has been newly introduced [13]. In the IAB network, an RLC backhaul channel is established for packet transmission between the IAB donor and the IAB nodes, through which data is transmitted. The BAP header contains the BAP routing ID, which is used to identify the destination of the packet.

In the first phase the IAB donor which plays the role of gNB, is connected to the CN via NG interface, the MT and UE of the nearby IAB node are connected through wireless access. At this time, the IAB donor is connected by treating the IAB node as a UE. In the second phase, the IAB node is connected to the far user through the DU via NR-Uu interface. IAB donor's coverage reaches both near user and IAB node, and IAB node covers both near user and far user. In order to perform NOMA, the MAC layer should schedule the same resource block signal between the IAB donor and the IAB node in the second transmission period. Fig. 4 shows the protocol stacks of NOMA-CDRT scenario separated by UP and CP.



(a) user plane



(b) control plane

Fig. 4: NOMA-CDRT protocol stack.

IV. Conclusions

This work presented the network architecture and protocol stacks of NOMA-CDRT. The relaying protocol in NOMA-CDRT was implemented using the IAB standard introduced in 3GPP. The protocol stacks for the UP and CP were proposed. Apart from IAB, 3GPP is working on other relaying protocols such as network controlled repeater (NCR) and intelligent reflecting surface (IRS). Implementing the relay protocol of NOMA-CDRT using NCR and IRS will be the subject of future research.

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