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METHOD AND APPARATUS FOR TRANSMITTING AND RECEIVING DATA DURING SCALING IN WIRELESS COMMUNICATION SYSTEM

Abstract

An operation method of a front-haul splitter in a wireless communication system, may include: receiving first downlink in-phase and quadrature (IQ) data from a first distributed unit (DU) connected to the front-haul splitter and second downlink IQ data from a second DU connected to the front-haul splitter; generating third downlink IQ data, based on the first downlink IQ data and the second downlink IQ data; and transmitting the third downlink IQ data to a radio unit (RU) connected to the front-haul splitter.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation application of International Application No. PCT/KR2023/017447, filed on Nov. 3, 2023, in the Korean Intellectual Property Receiving Office, which claims priority to Korean Patent Application No. 10-2022-0184833, filed on Dec. 26, 2022, in the Korean Intellectual Property Office, and Korean Patent Application No. 10-2023-0056583, filed on Apr. 28, 2023, in the Korean Intellectual Property Office, the disclosures of which are incorporated by reference herein in their entireties.

BACKGROUND

1. Field

[0002] In one or more embodiments, a method and apparatus for transmitting and receiving data during scaling in a wireless communication system may be provided.

2. Description of Related Art

[0003] In existing radio access network (RAN) systems, a distributed unit (DU) is connected one-to-one to a cell site, and the processing capacity of the DU is determined based on maximum traffic that can flow into the cell site. However, times when the maximum traffic occurs are limited, and a significant number of DU resources may not be used outside of these times. Therefore, the DU resources cannot be used efficiently.

[0004] Virtualized DU (vDU) pooling may refer to a technology capable of reducing the number of servers required to build a RAN system by breaking a 1:1 relationship between an existing DU and a cell site (a set of radio units (RUs)) and pooling and virtualizing DUs (capital expenditure (CAPEX) reduction). For example, before vDU pooling, four DUs, i.e., four servers, are required, but after vDU pooling, traffic coming from four cell sites may be handled using only three servers. In this way, because only three physical servers are actually operating, vDU pooling may also save power consumption compared to an existing RAN system that uses four physical servers (operational expenditure (OPEX) reduction).

[0005] In the above example, only DU pooling is described, but centralized units (CUs) may also be pooled like DUs. A RAN system that reduces CAPEX & OPEX by pooling and virtualizing DUs and CUs in this way is referred to as a virtualized RAN (vRAN) system.

SUMMARY

[0006] In such a vRAN system environment, there is a need for a method capable of efficiently transmitting and receiving data.

[0007] According to one or more example embodiments, an operation method of a front-haul splitter in a wireless communication system, may include: receiving first downlink in-phase and quadrature (IQ) data from a first distributed unit (DU) connected to the front-haul splitter and second downlink IQ data from a second DU connected to the front-haul splitter; generating third downlink IQ data, based on the first downlink IQ data and the second downlink IQ data; and transmitting the third downlink IQ data to a radio unit (RU) connected to the front-haul splitter.

[0008] According to one or more example embodiments, a front-haul splitter operating in a wireless communication system, may include: a transceiver; at least one processor coupled to the

transceiver to operate therewith; and memory storing instructions that, when executed by the at least one processor, cause the at least one processor to: control the transceiver to receive first downlink in-phase and quadrature (IQ) data from a first distributed unit (DU) connected to the front-haul splitter and second downlink IQ data from a second DU connected to the front-haul splitter; generate third downlink IQ data, based on the first downlink IQ data and the second downlink IQ data; and control the transceiver to transmit the third downlink IQ data to a radio unit (RU) connected to the front-haul splitter.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Embodiments will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings in which:

[0010] FIG. 1 is a diagram illustrating a wireless communication system according to one or more embodiments;

[0011] FIG. 2A is a diagram illustrating a wireless communication system before scale-out is performed, according to one or more embodiments;

[0012] FIG. 2B is a diagram illustrating a communication system in a state in which scale-out is being performed, according to one or more embodiments;

[0013] FIG. 2C is a diagram illustrating a communication system after scale-out is completed, according to one or more embodiments;

[0014] FIG. 3 is a device diagram of a front-haul splitter according to one or more embodiments;

[0015] FIG. 4 is a diagram illustrating an operation method of a front-haul splitter, according to one or more embodiments;

[0016] FIG. 5 is a diagram illustrating a method, performed by a front-haul splitter, of processing downlink data, according to one or more embodiments;

[0017] FIG. 6 is a diagram illustrating in-phase and quadrature (IQ) data according to one or more embodiments;

[0018] FIG. 7 is a diagram illustrating a transmission resource in which IQ data is transmitted, according to one or more embodiments;

[0019] FIG. 8A is a diagram illustrating a modulation scheme for downlink data transmitted on a physical downlink control channel (PDCCH) and a physical broadcast channel (PBCH), according to one or more embodiments;

[0020] FIG. 8B is a diagram illustrating a modulation scheme for downlink data transmitted on a physical downlink shared channel (PDSCH), according to one or more embodiments;

[0021] FIG. 9 is a diagram illustrating a method, performed by a front-haul splitter, of processing uplink data, according to one or more embodiments;

[0022] FIG. 10A is a diagram illustrating a communication system including a front-haul splitter, according to one or more embodiments;

[0023] FIG. 10B is a diagram illustrating an in-distributed unit (DU) embedded communication system including a DU pool 20 having a front-haul splitter therein, according to one or more embodiments; FIG. 10C is a diagram illustrating an in-radio unit (RU) embedded communication system including an RU having a front-haul splitter therein, according to one or more embodiments; and

[0024] FIG. 11 is a diagram illustrating a front-haul interface according to one or more embodiments.

DETAILED DESCRIPTION

[0025] Throughout the present disclosure, the expression “at least one of a, b or c” indicates only a, only b, only c, both a and b, both a and c, both b and c, all of a, b, and c, or variations thereof.

[0026] The terms used in the present disclosure may be general terms currently widely used in the art by taking into account functions described herein, but may vary according to an intention of a technician engaged in the art, precedent cases, advent of new technologies, etc. Furthermore, specific terms may be arbitrarily selected by the applicant, and in this case, the meaning of the selected terms will be described in detail in the relevant description. Thus, the terms used herein should be defined not by simple appellations thereof but based on the meaning of the terms together with the overall description of the present disclosure.

[0027] Singular expressions used herein are intended to include plural expressions as well unless the context clearly indicates otherwise. All the terms used herein, which include technical or scientific terms, may have the same meaning that is generally understood by one of ordinary skill in the art. Furthermore, although the terms including an ordinal number such as “first”, “second”, etc. may be used herein to describe various elements or components, these elements or components should not be limited by the terms. The terms are only used to distinguish one element or component from another element or component.

[0028] Throughout the specification, when a part “includes” or “comprises” an element, unless there is a particular description contrary thereto, it is understood that the part may further include other elements, not excluding the other elements. In addition, terms such as “unit”, “module”, etc., described herein refer to a unit for processing at least one function or operation and may be implemented as hardware or software, or a combination of hardware and software.

[0029] Embodiments of the present disclosure will be described more fully hereinafter with reference to the accompanying drawings so that they may be easily implemented by one of ordinary skill in the art. However, the present disclosure may be implemented in many different forms and should not be construed as being limited to one or more embodiments set forth herein. Furthermore, parts not related to the descriptions are omitted to clearly explain the present disclosure in the drawings, and like reference numerals denote like elements throughout. In addition, reference numerals used in each drawing are only intended to describe each drawing, and different reference numerals used in different drawings are not intended to indicate different elements. Hereinafter, the present disclosure is described in detail with reference to the accompanying drawings.

[0030] FIG. 1 is a diagram illustrating a wireless communication system according to one or more embodiments.

[0031] In the present disclosure, a wireless communication system may include at least one radio unit (RU) **110**, at least one distributed unit (DU) **120**, and a centralized unit (CU) **130**. In the present disclosure, the wireless communication system may refer to, but is not limited to, a virtualized radio access network (vRAN). For example, the wireless communication system may include a fifth-generation (5G) system (5GS), a fourth-generation (4G) system (4GS), or other wireless communication systems, and may also refer to a wireless communication system to be developed in the future.

[0032] In the present disclosure, splitting the functions of layers handled by the CU **130** and the DU **120** among protocol layers of a network may be referred to as a higher layer split.

[0033] The CU **130** may refer to an entity performing functions of some of the protocol layers of the network. For example, the CU **130** may refer to an entity performing network functions of a Radio Resource control (RRC) layer and a Packet Data Convergence Protocol (PDCP) layer. However, the functions of some of the layers that may be handled by the CU **130** are not limited to those of the RRC layer and the PDCP layer. For example, the CU **130** may refer to a virtualized CU (vCU) of a vRAN system, but is not limited thereto.

[0034] A DU pool **160** may refer to a set including the at least one DU **120**.

[0035] The DU **120** may be an entity performing functions of some of the remaining protocol layers of the network other than the layers whose functions are performed by the CU **130**. For example, the DU **120** may refer to an entity that performs network functions (e.g., baseband

functions) of a Radio Link Control (RLC) layer, a Medium Access Control (MAC) layer, and a Physical (PHY) layer. However, the functions of some of the layers that may be handled by the DU **120** are not limited to those of the RLC layer, the MAC layer, and the PHY layer. For example, the DU **120** may refer to a virtualized DU (vDU) of the vRAN system, but is not limited thereto. For example, the DU **120** may correspond to a processing pod, a component module, a processing operation unit, a deployment unit performing some processing, or the like. For example, the DU **120** may correspond to a server.

[0036] In the present disclosure, splitting the functions of layers handled by the DU **120** and the RU **110** among the protocol layers of the network may be referred to as a lower layer split. For example, functions of the PHY layer handled by the DU **120** may be further split between the DU **120** and the RU **110**. The lower-layer split is described in more detail below with reference to FIG. **11**.

[0037] The RU **110** may refer to an entity that performs some of the functions of the PHY layer other than functions handled by DU **120**. For example, the RU **110** may refer to a virtualized RU (vRU) of the vRAN system, but is not limited thereto.

[0038] One CU **130** may be connected to N DUs **120**, where N may be any integer greater than 1. The CU **130** and the DU **120** may be connected via an interface **150**. For example, the interface **150** between the CU **130** and the DU **120** may be an F1 interface. For example, the functions of the RRC layer and the PDCP layer that may be handled by the CU **130** may be centralized, and thus, anchor changes in the RRC layer and the PDCP layer may not be performed during a baseband handover across the DUs **120**. Thus, the quality of services associated with handovers occurring within the same CU **130** may be improved. In addition, the CU **130** may increase resource efficiency by pooling resources across multiple DUs **120**.

[0039] One DU **120** may be connected to M RUs **110**, where M may be any integer greater than 1. The DU **120** and the RU **110** may be connected via an interface **140**, and for example, the interface **140** between the DU **120** and the RU **110** may be a front-haul interface. As a non-limiting example, the interface **140** between the DU **120** and the RU **110** may be ORAN FH (option 7.2) in the open RAN (ORAN) or IF 4p5 (option 7.2x) in OpenAirInterface (OAI).

[0040] One DU **120** may manage at least one cell. In addition, each cell may correspond to the RU **110** (i.e., the cell and the RU **110** have a one-to-one relationship). Therefore, the cells and the RUs **110** connected to the one DU **120** may be connected via a 1:1 interface.

[0041] In the present disclosure, the number of DUs **120** in the DU pool **160** may be increased or decreased. When the DU **120** is added to the DU pool **160**, a processing pod corresponding to the DU **120** may be increased to distribute the added DU **120**.

[0042] Referring to FIG. **1**, the RU **110**, the DU **120**, and the CU **130** may be configured with a topology of M:N:1 ($M > N > 1$). Each DU **120** may be allocated enough computational resources to process the maximum data capacity of the RU **110**. In this case, if traffic handled by the RU **110** is about 20% of the maximum data capacity of the RU **110**, more resources than necessary are allocated to the DU **120**. Therefore, the static resource allocation method as described above increases the investment cost of the server and causes an increase in power consumption.

[0043] Accordingly, in the vRAN system, a vDU scaling method may be used to efficiently use server resources by dynamically scaling in or out the DU **120** according to a current traffic situation. However, because a current wireless communication system does not support dynamically scaling in or out the DU **120**, there is a need for a method capable of scaling the DU **120** without disconnecting a terminal (or a user equipment (UE)) connected to the RU **110**.

[0044] In the present disclosure, a method of performing seamless DU scale-out and scale-in may be provided with reference to the following drawings.

[0045] FIG. **2A** is a diagram illustrating a wireless communication system before scale-out is performed, according to one or more embodiments.

[0046] The DU pool **20** may include a first DU **22**. The DU pool **20** may further include at least

one more DU.

[0047] One CU **210** may be connected to the first DU **22**, and the first DU **22** may be connected to a first RU **30** and a second RU **230**. The first DU **22** may be connected to the first RU **30** via a first front-haul interface **240**, and may be connected to the second RU **230** via a second front-haul interface **242**.

[0048] The first DU **22** manages two cells, i.e., a first cell and a second cell. The first RU **30** may correspond to the first cell, and the first cell may include a first UE **250** and a second UE **252**. The second RU **230** may correspond to the second cell, and the second cell may include a third UE **254**. The first RU **30** may be connected to the first UE **250** and the second UE **252**, and the second RU **230** may be connected to the third UE **254**. However, FIG. 2A is only a diagram illustrating an example of the wireless communication system, and the wireless communication system may further include a plurality of UEs, a plurality of RUs, and a plurality of DUs.

[0049] FIG. 2B is a diagram illustrating a communication system in a state in which scale-out is being performed, according to one or more embodiments.

[0050] When the amount of data generated in the first cell increases, the amount of data that needs to be processed by the first DU **22** may increase. In this case, to prevent excessive traffic processing load on the first DU **22**, it may be necessary to effectively process the data generated in the first cell. At this time, the wireless communication system may use a new DU to process the data generated in the first cell. In this case, an RU associated with the first cell may also be migrated to the new DU.

[0051] In one or more embodiments, the first RU **30** may refer to an RU corresponding to the first cell, from which the data is to be transferred, and may refer to a migrate RU to be migrated.

[0052] When the amount of traffic to be handled in the first DU **22** increases, a second DU **24** may be added to the DU pool **20** to distribute or migrate and handle the increased traffic. The second DU **24** may refer to a DU to which scale-out is applied.

[0053] In the present disclosure, scale-out may refer to adding the second DU **24** to the DU pool **20**. For example, when the amount of traffic that the first DU **22** included in the DU pool **20** needs to handle increases, the second DU **24** may be added. Adding the second DU **24** to the DU pool **20** may refer to adding a processing pod corresponding to the second DU **24** to the DU pool **20**. For example, adding the second DU **24** to the DU pool **20** may mean that an additional server capable of processing data starts operating. By using scale-out, the second DU **24** (a server with similar specifications, as a non-limiting example) may be added to the communication system when the capacity or performance of the first DU **22** (e.g., an existing server) to process data reaches its limit.

[0054] In the present disclosure, scale-in may refer to removing the second DU **24** included in the DU pool **20**. For example, when the amount of traffic that DUs included in the DU pool **20** have to handle decreases, the second DU **24** may be removed from the DU pool **20**. Removing the second DU **24** from the DU pool **20** may refer to removing a processing pod corresponding to the second DU **24** to the DU pool **20**. For example, removing the second DU **24** from the DU pool **20** may mean that the server processing the data stops operating. By using scale-in, the number of servers that no longer need to operate may be reduced, and resources may be saved.

[0055] When scale-out is performed, the second DU **24** has to be connected to the first RU **30** in order to process data generated in the first cell corresponding to the first RU **30**. In this case, in order to prevent interruptions in data transmission or data processing, the first DU **22** and the second DU **24** may be simultaneously connected to the first RU **30**. While scale-out is being performed, the first RU **30** may be simultaneously connected to the first DU **22** and the second DU **24**. The first RU **30** may be connected to the first DU **22** via the first front-haul interface **240**. The first RU **30** may be connected to the second DU **24** via a third front-haul interface **244**.

[0056] FIG. 2C is a diagram illustrating a communication system after scale-out is completed, according to one or more embodiments.

[0057] If data in the first RU **30** is stably migrated to the second DU **24**, the scale-out may be completed. In this case, the first RU **30** is connected to the second DU **24** via the third front-haul interface **244**, so that data generated in the first cell may be processed in the second DU **24**. The second RU **230** is connected to the first DU **22** via the second front-haul interface **242**, so that data generated in the second cell may be processed in the first DU **22**.

[0058] Referring to FIG. **1**, one DU **120** may be connected to a plurality of RUs **110**, but one RU **110** may be connected to only one DU **120**. However, referring to FIG. **2B**, when scale-out is performed, the first RU **30** may be connected to the plurality of DUs (i.e., the first DU **22** and the second DU **24**). In this case, the first RU **30** will receive a plurality of pieces of downlink data from the plurality of DUs (i.e., the first DU **22** and the second DU **24**), and therefore, a method of processing the plurality of pieces of downlink data is required. In addition, the first RU **30** will transmit uplink data to the plurality of DUs (i.e., the first DU **22** and the second DU **24**), and therefore, a method of processing the uplink data is required.

[0059] In one or more embodiments, a front-haul splitter **10** and an operation method of the front-haul splitter **10** may be provided to enable communication between the plurality of DUs and the first RU **30** when scale-out is performed.

[0060] In one or more embodiments, the front-haul splitter **10** may refer to an entity that processes in-phase and quadrature (IQ) data received from the plurality of DUs (e.g., the first DU **22** and the second DU **24**) and transmits the processed IQ data to the first RU **30**, or processes IQ data received from the first RU **30** and transmits the processed IQ data to the plurality of DUs (e.g., the first DU **22** and the second DU **24**). The front-haul splitter **10** may be implemented as an electronic device or a software module. For example, the front-haul splitter **10** may be implemented as a separate electronic device that is separated from the DU pool **20** and the first RU **30**. For example, the front-haul splitter **10** may be implemented as an electronic device or software module included in the DU pool **20** or the first RU **30**.

[0061] In one or more embodiments, the methods described below may also be applied when scale-in is performed.

[0062] FIG. **3** is a device diagram of the front-haul splitter **10** according to one or more embodiments.

[0063] The front-haul splitter **10** may be composed of a transceiver **310**, a processor **320**, and a memory **330**. The components of the front-haul splitter **10** are not limited to the above example. For example, the front-haul splitter **10** may include more or fewer components than the components described above. In one or more embodiments, the transceiver **310**, the processor **320**, and the memory **330** may be implemented in the form of a single chip. Furthermore, the processor **320** may include one or more processors. The processor **320** may comprise processing circuitry. The memory may store instructions that, when executed by the one or more processors individually or collectively, cause the one or more processors to perform operations as described herein.

[0064] The transceiver **310** collectively refers to a receiver of the front-haul splitter **10** and a transmitter of the front-haul splitter **10**, and may transmit and receive signals to and from a UE or network entity, the DU pool **20**, the CU **210**, and the first RU **30**. The signals transmitted to and received from the UE or network entity may include control information and data. To achieve this, the transceiver **310** may include an RF transmitter for up-converting and amplifying a frequency of a signal being transmitted and an RF receiver for low-noise amplifying a received signal and down-converting its frequency. However, this is merely one or more embodiments of the transceiver **310**, and components of the transceiver **310** are not limited to the RF transmitter and the RF receiver.

[0065] Additionally, the transceiver **310** may perform functions for transmitting and receiving signals via a radio channel. For example, the transceiver **310** may receive a signal via a radio channel and output the signal to the processor **320** and transmit a signal output from the processor **320** via the radio channel.

[0066] The memory **330** may store data and programs necessary for operations of the front-haul

splitter **10**. Furthermore, the memory **330** may store control information or data in a signal obtained by a device (e.g., the front-haul splitter **10**). The memory **330** may comprise one or more storage mediums. The memory **330** may include storage media such as read-only memory (ROM), random access memory (RAM), hard discs, compact disc ROM (CD-ROM), and digital video discs (DVDs), or a combination of the storage media. Furthermore, the memory **330** may not exist separately but may be configured to be included in the processor **320**. The memory **330** may consist of volatile memory, non-volatile memory, or a combination of volatile and non-volatile memory. The memory **330** may also provide stored data according to a request from the processor **320**.

[0067] The memory **330** may include at least one first module **332**, or a second module **334**. For example, the first module **332** may refer to a software module for processing downlink data received by the front-haul splitter **10**. For example, the first module **332** may refer to a software module for processing a plurality of pieces of downlink IQ data received by the front-haul splitter **10** from the DU pool **20** and transmitting the resulting downlink IQ data to the first RU **30**. For example, the second module **334** may refer to a software module for processing uplink data received by the front-haul splitter **10**. For example, the second module **334** may refer to a software module for processing uplink IQ data received by the front-haul splitter **10** from the first RU **30** and transmitting the uplink IQ data to the DU pool **20**.

[0068] The processor **320** may control a series of processes such that the front-haul splitter **10** may operate according to the embodiment of the present disclosure. For example, the processor **320** may receive control signals and data signals via the transceiver **310** and process the received control signals and data signals. The processor **320** may transmit the processed control signals and data signals via the transceiver **310**. In addition, the processor **320** may write data to and read data from the memory **330**. The processor **320** may perform functions of a protocol stack required by communication standards. To this end, the processor **320** may include at least one processor or microprocessor. In one or more embodiments, a portion of the transceiver **310** or the processor **320** may be referred to as a communication processor (CP).

[0069] The processor **320** may be configured as one or a plurality of processors. In this case, the one or plurality of processors may be a general-purpose processor such as a central processing unit (CPU), an application processor (AP), a digital signal processor (DSP), etc., a dedicated graphics processor, such as a graphics processing unit (GPU) and a vision processing unit (VPU), or a dedicated artificial intelligence (AI) processor, such as a neural processing unit (NPU). For example, if the one or plurality of processors is a dedicated AI processor, the dedicated AI processor may be designed with a hardware structure specialized for processing a specific AI model.

[0070] In one or more embodiments, the processor **320** may control the transceiver **310** to receive first downlink IQ data **510** of FIG. 5 from the first DU **22** connected to the front-haul splitter **10** and second downlink IQ data **520** of FIG. 5 from the second DU **24** connected to the front-haul splitter **10**.

[0071] In one or more embodiments, the processor **320** may generate third downlink IQ data **530** of FIG. 5, based on the first downlink IQ data and the second downlink IQ data.

[0072] In one or more embodiments, the processor **320** may control the transceiver **310** to transmit the third downlink IQ data **530** of FIG. 5 to the first RU **30** connected to the front-haul splitter **10**.

[0073] In one or more embodiments, the processor **320** may control the transceiver **310** to transmit identification information of the front-haul splitter **10** to the at least one of first DU **22**, the second DU **24**, or the first RU **30**.

[0074] In one or more embodiments, the processor **320** may control the transceiver **310** to receive first uplink IQ data **910** of FIG. 9 from the first RU **30**.

[0075] In one or more embodiments, the processor **320** may identify second uplink IQ data **920** of FIG. 9 based on at least one of the first uplink IQ data **910** of FIG. 9, information about a target

DU, or the number of DUs connected to the front-haul splitter **10**.

[0076] In one or more embodiments, the processor **320** may control the transceiver **310** to transmit the second uplink IQ data **920** of FIG. **9** to the first DU **22**.

[0077] In one or more embodiments, the processor **320** may control the transceiver **310** to transmit third uplink IQ data **930** of FIG. **9** to the second DU **24**.

[0078] In one or more embodiments, the processor **320** may control the transceiver **310** to receive scheduling information from the at least one first DU **22** or the second DU **24**.

[0079] In one or more embodiments, the processor **320** may identify information about a target DU based on the scheduling information.

[0080] FIG. **4** is a diagram illustrating an operation method of the front-haul splitter **10**, according to one or more embodiments.

[0081] In one or more embodiments, the front-haul splitter **10** may be included in the DU pool **20** including the first DU **22** and the second DU **24**.

[0082] In one or more embodiments, the front-haul splitter **10** may be included in the first RU **30**.

[0083] In operation **S 410**, the front-haul splitter **10** may receive the first downlink IQ data **510** from the first DU **22** connected to the front-haul splitter **10** and the second downlink IQ data **520** from the second DU **24** connected to the front-haul splitter **10**.

[0084] In one or more embodiments, the first downlink IQ data **510** and the second downlink IQ data **520** may be received based on identification information of the front-haul splitter **10**.

[0085] In one or more embodiments, the first downlink IQ data **510** and the second downlink IQ data **520** may be received based on time resource allocation information. For example, the time resource allocation information may include information about allocated slots or symbols.

[0086] In operation **S420**, the front-haul splitter **10** may generate the third downlink IQ data **530**, based on the first downlink IQ data **510** and the second downlink IQ data **520**.

[0087] In one or more embodiments, the first downlink IQ data **510** may be correspond to downlink data.

[0088] In one or more embodiments, the second downlink IQ data **520** may be correspond to downlink data.

[0089] In one or more embodiments, the second downlink IQ data **520** may be a value of (0,0).

[0090] In one or more embodiments, the third downlink IQ data **530** may correspond to a value of a vector sum of the first downlink IQ data **510** and the second downlink IQ data **520**.

[0091] In operation **S430**, the front-haul splitter **10** may transmit the third downlink IQ data **530** to the first RU **30** connected to the front-haul splitter **10**.

[0092] In one or more embodiments, the front-haul splitter **10** may transmit identification information of the front-haul splitter **10** to the at least one of first DU **22**, the second DU **24**, or the first RU **30**.

[0093] In one or more embodiments, the identification information of the front-haul splitter **10** may include at least one MAC address of the front-haul splitter **10**, or identification information associated with an Internet Protocol (IP) of the front-haul splitter **10**. For example, the identification information associated with the IP of the front-haul splitter **10** may include at least one IP port information, or an IP address.

[0094] In one or more embodiments, the third downlink IQ data **530** may be transmitted based on the identification information of the front-haul splitter **10**.

[0095] In one or more embodiments, the front-haul splitter **10** may transmit the third uplink IQ data **930** to the second DU **24**.

[0096] In one or more embodiments, the second uplink IQ data **920** and the third uplink IQ data **930** may each include the same value as the first uplink IQ data **910**.

[0097] In one or more embodiments, the second uplink IQ data **920** and the third uplink IQ data **930** may be a replicated version of the first uplink IQ data **910**, based on the number of DUs connected to the front-haul splitter **10**.

[0098] In one or more embodiments, the front-haul splitter **10** may receive scheduling information from the at least one first DU **22**, or the second DU **24**.

[0099] In one or more embodiments, the front-haul splitter **10** may identify information about a target DU based on the scheduling information.

[0100] In one or more embodiments, based on the information about the target DU, the first DU **22** may be identified as a target DU for transmitting the second uplink IQ data **920** including the same value as the first uplink IQ data **910**.

[0101] In one or more embodiments, the first uplink IQ data **910** may be received based on the identification information of the front-haul splitter **10**.

[0102] In one or more embodiments, the second uplink IQ data **920** and the third uplink IQ data **930** may be transmitted based on the identification information of the front-haul splitter **10**.

[0103] In one or more embodiments, the identification information of the front-haul splitter **10** may include at least one MAC address of the front-haul splitter **10**, or identification information associated with an IP of the front-haul splitter **10**. For example, the identification information associated with the IP of the front-haul splitter **10** may include at least one IP port information, or an IP address.

[0104] FIG. **5** is a diagram illustrating a method, performed by the front-haul splitter **10**, of processing downlink data, according to one or more embodiments.

[0105] In one or more embodiments, downlink data may refer to data that is transmitted from the DU pool **20** to the first RU **30**. Physical channels for transmitting the downlink data may include a PDCCH, a PDSCH, and a PBCH. For example, a PDCCH may refer to a channel used to transmit control information (e.g., downlink control information (DCI)), but is not limited to the stated example. A PDSCH may refer to a channel used to transmit user data, but is not limited to the stated example. A PBCH refers to a channel for carrying a broadcast message, and for example, may refer to a channel for transmitting cell system information, but is not limited to the stated example.

[0106] In one or more embodiments, the downlink data may be transmitted in the form of IQ data. The front-haul splitter **10** may receive the first downlink IQ data **510** from the first DU **22** via a front-haul interface. The front-haul splitter **10** may receive the second downlink IQ data **520** from the second DU **24** via the front-haul interface. The front-haul splitter **10** may generate the third downlink IQ data **530**, based on at least one of the first downlink IQ data **510** or the second downlink IQ data **520**.

[0107] A method by which the front-haul splitter **10** connected to the plurality of DUs receives the plurality of pieces of downlink IQ data and generates one piece of third downlink IQ data **530** for transmission to the first RU **30** is described in more detail below.

[0108] FIG. **6** is a diagram illustrating IQ data according to one or more embodiments.

[0109] In one or more embodiments, the first downlink IQ data **510**, the second downlink IQ data **520**, and the third downlink IQ data **530** may be data in the same format as IQ data **610**.

[0110] In the present disclosure, a plurality of DUs may transmit and receive IQ data to and from an RU. Accordingly, the front-haul splitter **10** may process the IQ data **610** transmitted and received between the plurality of DUs and the RU.

[0111] FIG. **6** is a diagram illustrating the IQ data **610** in an IQ plane **600**. The horizontal axis on the IQ plane **600** may represent an in-phase (I) component, and an I value **620** of the IQ data **610** may represent a component having the same phase as the IQ data **610**. The vertical axis on the IQ plane **600** may represent a quadrature (Q) component, and a Q value **630** of the IQ data **610** may represent a component that is 90° out of phase with respect to the IQ data **610**. In addition, a length **640** of a vector of the IQ data **610** may represent an amplitude of the IQ data **610**.

[0112] FIG. **7** is a diagram illustrating a transmission resource in which IQ data is transmitted, according to one or more embodiments.

[0113] For example, the first DU **22** and the second DU **24** may transmit downlink IQ data to the

front-haul splitter **10** by using scheduled resources. The downlink IQ data may be modulated by using a specific transmission resource (e.g., a resource element (RE)) in a resource grid via a predetermined scheme, and transmitted to the front-haul splitter **10**.

[0114] The front-haul splitter **10** may receive the first downlink IQ data **510** from the first DU **22** by using a first resource **710** allocated to the first DU **22**. The front-haul splitter **10** may receive the second downlink IQ data **520** from the second DU **24** by using a second resource **720** allocated to the second DU **24**. For example, the allocated first resource **710** and the allocated second resource **720** may each correspond to at least one RE, but are not limited thereto.

[0115] The first DU **22** and the second DU **24** may each convert the downlink data by using a predetermined modulation scheme and transmit the modulated data to the front-haul splitter **10** in the form of IQ data. The front-haul splitter **10** may generate the third downlink IQ data **530**, based on the first downlink IQ data **510** and the second downlink IQ data **520**. A method of generating the third downlink IQ data **530** is described in detail below with reference to FIGS. **8A** and **8B**.

[0116] FIG. **8A** is a diagram illustrating a modulation scheme for downlink data transmitted on a PDCCH and a PBCH, according to one or more embodiments.

[0117] The DUs included in the DU pool **20** may determine a modulation scheme for downlink data based on characteristics of the downlink data to be transmitted.

[0118] For example, downlink data transmitted on a PDCCH and downlink data transmitted on a PBCH may be modulated using a quadrature phase-shift keying (QPSK) scheme **810** as shown in FIG. **8A**, but are not limited to the above-described example. PSK modulation may refer to a method of distinguishing signals by using only a direction. For example, downlink data transmitted on a PDCCH and downlink data transmitted on a PBCH may be modulated using a PSK scheme.

[0119] In one or more embodiments, when downlink data is transmitted on a PDCCH, the first DU **22** may transmit an IQ data value corresponding to the downlink data to the front-haul splitter **10**, and the second DU **24** may transmit an IQ data value corresponding to the downlink data to the front-haul splitter **10**. That is, the first downlink IQ data **510** and the second downlink IQ data **520** may both have the same value. For example, when a plurality of DUs transmit pieces of downlink data to the front-haul splitter **10** on a PDCCH, the plurality of DUs may transmit a plurality of pieces of IQ data having the same value to the front-haul splitter **10**. The front-haul splitter **10** may reconstruct signals transmitted by the plurality of DUs by calculating a vector sum for the received plurality of pieces of IQ data. Therefore, the front-haul splitter **10** may generate the third downlink IQ data **530** with a value equal to a value of the vector sum of the first downlink IQ data **510** and the second downlink IQ data **520**.

[0120] In one or more embodiments, when downlink data is transmitted on a PDCCH, the first DU **22** may transmit an IQ data value corresponding to the downlink data to the front-haul splitter **10**, and the second DU **24** may transmit a value (0, 0) to the front-haul splitter **10**. That is, the first downlink IQ data **510** correspond to the downlink data, and the second downlink IQ data **520** may be the value (0, 0). For example, when a plurality of DUs (e.g., N DUs) transmit pieces of downlink data to the front-haul splitter **10** on a PDCCH, the DUs may transmit signals by allocating REs in a mutually exclusive manner. For this reason, one DU may transmit an IQ data value corresponding to downlink data to the front-haul splitter **10**, while the remaining DUs (e.g., N-1 DUs) may transmit a plurality of pieces of IQ data each with a value of (0, 0) to the front-haul splitter **10**. The front-haul splitter **10** may reconstruct signals transmitted by the plurality of DUs by calculating a vector sum for the received plurality of pieces of IQ data. Therefore, the front-haul splitter **10** may generate the third downlink IQ data **530** with a value equal to a value of the vector sum of the first downlink IQ data **510** and the second downlink IQ data **520**.

[0121] In one or more embodiments, when downlink data is transmitted on a PBCH, the first DU **22** may transmit an IQ data value corresponding to the downlink data to the front-haul splitter **10**, and the second DU **24** may transmit an IQ data value corresponding to the downlink data to the front-haul splitter **10**. That is, the first downlink IQ data **510** and the second downlink IQ data **520**

may both have the same value. For example, when a plurality of DUs transmit pieces of downlink data to the front-haul splitter **10** on a PBCH, the plurality of DUs may transmit a plurality of pieces of IQ data having the same value to the front-haul splitter **10**. The front-haul splitter **10** may reconstruct signals transmitted by the plurality of DUs by calculating a vector sum for the received plurality of pieces of IQ data. Therefore, the front-haul splitter **10** may generate the third downlink IQ data **530** with a value equal to a value of the vector sum of the first downlink IQ data **510** and the second downlink IQ data **520**.

[0122] In one or more embodiments, when downlink data is transmitted on a PBCH, the first DU **22** may transmit an IQ data value corresponding to the downlink data to the front-haul splitter **10**, and the second DU **24** may transmit a value (0, 0) to the front-haul splitter **10**. That is, the first downlink IQ data **510** may correspond to the downlink data, and the second downlink IQ data **520** may be the value (0, 0). For example, when a plurality of DUs (e.g., N DUs) transmit pieces of downlink data to the front-haul splitter **10** on a PBCH, the DUs may transmit signals by allocating REs in a mutually exclusive manner. For this reason, one DU may transmit an IQ data value corresponding to the downlink data to the front-haul splitter **10**, while the remaining DUs (e.g., N-1 DUs) may transmit pieces of IQ data with a value of (0, 0) to the front-haul splitter **10**. The front-haul splitter **10** may reconstruct signals transmitted by the plurality of DUs by calculating a vector sum for the received plurality of pieces of IQ data. Therefore, the front-haul splitter **10** may generate the third downlink IQ data **530** with a value equal to a value of the vector sum of the first downlink IQ data **510** and the second downlink IQ data **520**.

[0123] FIG. **8B** is a diagram illustrating a modulation scheme for downlink data transmitted on a PDSCH, according to one or more embodiments.

[0124] FIG. **8B** is a diagram illustrating IQ data modulated using a 16 quadrature amplitude modulation (16-QAM) scheme. For example, downlink data transmitted on a PDSCH may be modulated using a PSK or QAM scheme, but is not limited to the stated examples. The QAM scheme may refer to a method of distinguishing signals by using both direction and magnitude. As a non-limiting example, PSK may include QPSK, 8-PSK, 16-PSK, and 32-PSK, etc. As a non-limiting example, QAM may include 4-QAM, 16-QAM, 64-QAM, and 256-QAM, etc.

[0125] In one or more embodiments, when downlink data is transmitted on a PDSCH, the first DU **22** may transmit an IQ data value corresponding to the downlink data to the front-haul splitter **10**, and the second DU **24** may transmit a value (0, 0) to the front-haul splitter **10**. That is, the first downlink IQ data **510** may correspond to the downlink data, and the second downlink IQ data **520** may be the value (0, 0). For example, when a plurality of DUs (e.g., N DUs) transmit pieces of downlink data to the front-haul splitter **10** on a PDSCH, the DUs may transmit signals on the PDSCH by allocating REs in an mutually exclusive manner. For this reason, a particular DU may transmit an IQ data value corresponding to the downlink data to the front-haul splitter **10**, while the remaining DUs (e.g., N-1 DUs) may transmit pieces of IQ data with a value of (0, 0) to the front-haul splitter **10**. The front-haul splitter **10** may reconstruct signals transmitted by the plurality of DUs by calculating a vector sum for the received plurality of pieces of IQ data. Therefore, the front-haul splitter **10** may generate the third downlink IQ data **530** with a value equal to a value of the vector sum of the first downlink IQ data **510** and the second downlink IQ data **520**.

[0126] In one or more embodiments, the front-haul splitter **10** may receive a plurality of pieces of downlink IQ data in the frequency domain for every slot or every symbol. The front-haul splitter **10** may generate the third downlink IQ data **530** by merging the plurality of pieces of downlink IQ data. The front-haul splitter **10** may transmit the third downlink IQ data **530** to the first RU **30**. The first RU **30** may receive the third downlink IQ data **530** and identify the third downlink IQ data **530**.

[0127] In one or more embodiments, the front-haul splitter **10** may identify the first RU **30** based on identification information of the first RU **30**. The identification information of the first RU **30** may include address information of the first RU **30**.

[0128] FIG. 9 is a diagram illustrating a method, performed by the front-haul splitter **10**, of processing downlink data, according to one or more embodiments.

[0129] In one or more embodiments, uplink data may refer to data that is transmitted from the first RU **30** to the DU pool **20**. Physical channels for transmitting the uplink data may include a physical random access channel (PRACH), a physical uplink control channel (PUCCH), and a physical uplink shared Channel (PUSCH). For example, a PUCCH may refer to a channel used to transmit control information, but is not limited to the stated example. A PUSCH may refer to a channel used to transmit user data, but is not limited to the stated example. A PRACH may refer to a channel for transmitting messages for performing random access, but is not limited to the stated example.

[0130] In one or more embodiments, the uplink data may be transmitted in the form of IQ data. The front-haul splitter **10** may receive the first uplink IQ data **910** from the first RU **30** via a front-haul interface.

[0131] In one or more embodiments, the front-haul splitter **10** may receive one piece of uplink IQ data from the first RU **30** and generate uplink IQ data for transmission to a plurality of DUs. For example, the front-haul splitter **10** may generate, based on the first uplink IQ data **910**, at least one of the second uplink IQ data **920** or the third uplink IQ data **930**.

[0132] In one or more embodiments, the first uplink IQ data **910**, the second uplink IQ data **920**, and the third uplink IQ data **930** may be data in the same format as the IQ data **610**.

[0133] For example, the first RU **30** may transmit the first uplink IQ data **910** to the front-haul splitter **10** by using scheduled resources. The first uplink IQ data **910** may be modulated by using a specific transmission resource (e.g., an RE) within the resource grid via a predetermined scheme, and transmitted to the front-haul splitter **10**.

[0134] In one or more embodiments, the front-haul splitter **10** may transmit the second uplink IQ data **920** to the first DU **22** and the third uplink IQ data **930** to the second DU **24**. The second uplink IQ data **920** and the third uplink IQ data **930** may each include the same value as the first uplink IQ data **910**. Due to the nature of the MAC layer, a DU may only extract and process only resources (e.g., REs) that contain necessary data. Accordingly, the front-haul splitter **10** may duplicate and transmit uplink IQ data to a plurality of DUs connected to the front-haul splitter **10** without identifying which of the plurality of DUs connected to the front-haul splitter **10** is a target DU to which the uplink IQ data needs to be delivered. For example, when uplink data is transmitted on a PRACH (e.g., PRACH signal or PRACH data), only one of the N DUs needs to process a PRACH, so even when all the DUs receive PRACHs, only one DU needs to perform a PRACH procedure. Accordingly, the front-haul splitter **10** may duplicate and transmit the first uplink IQ data **910** received from the first RU **30** to all connected DUs.

[0135] In one or more embodiments, when duplicating and transmitting an uplink data packet, the front-haul splitter **10** may duplicate and transmit the packet by using broadcast or multicast at the Ethernet or IP layer. For example, a duplication function provided at the Ethernet or IP layer may be used.

[0136] In one or more embodiments, the front-haul splitter **10** may identify a target DU to which uplink IQ data is to be transmitted. The front-haul splitter **10** may identify the first DU **22** as the target DU to which the uplink IQ data is to be transmitted, from among the plurality of DUs. The front-haul splitter **10** may transmit, to the first DU **22**, the second uplink IQ data **920** including the same value as the first uplink IQ data **910**.

[0137] In one or more embodiments, the front-haul splitter **10** may receive, from the first RU **30**, the first uplink IQ data **910** in the frequency domain for every slot or symbol. For example, the front-haul splitter **10** may receive the first uplink IQ data **910** from a low-PHY process. For example, the front-haul splitter **10** may duplicate the first uplink IQ data **910** to generate the second uplink IQ data **920** and the third uplink IQ data **930**.

[0138] The front-haul splitter **10** may transmit the second uplink IQ data **920** to the first DU **22**. The first DU **22** may receive the second uplink IQ data **920**, and identify the second uplink IQ data

920.

[0139] The front-haul splitter **10** may transmit the third uplink IQ data **930** to the second DU **24**. The second DU **24** may receive the third uplink IQ data **930**, and identify the third uplink IQ data **930**.

[0140] In one or more embodiments, the front-haul splitter **10** may identify the first DU **22** based on identification information of the first DU **22**. The identification information of the first DU **22** may include address information of the first DU **22**.

[0141] In one or more embodiments, the front-haul splitter **10** may identify the second DU **24** based on identification information of the second DU **24**. The identification information of the second DU **24** may include address information of the second DU **24**.

[0142] In one or more embodiments, if the front-haul splitter **10** has identified in advance a DU to which specific uplink data (e.g., RE, PRACH signal, etc.) needs to be transmitted, the front-haul splitter **10** may adopt a method of transmitting the uplink data only to the identified DU.

[0143] In one or more embodiments, the front-haul splitter **10** may identify a type of uplink data. Based on the type of uplink data, a DU to which the corresponding uplink data is to be transmitted may be identified among the plurality of DUs.

[0144] In one or more embodiments, depending on the implementation and operational efficiency of the front-haul splitter **10**, the front-haul splitter **10** may exist within the first RU **30**, exist within the DU pool **20**, or exist as a separate entity or component between the first RU **30** and the DU pool **20**.

[0145] FIG. **10A** is a diagram illustrating a communication system **1040** including the front-haul splitter **10**, according to one or more embodiments.

[0146] FIG. **10A** is a diagram illustrating communication when the front-haul splitter **10** exists as an independent entity or component within the communication system **1040**.

[0147] In the present disclosure, the first RU **30** may include a front-haul handler module **1010**, a low-PHY module **1020**, and an RF module **1030**. A configuration of the first RU **30** is not limited to the above-described example, and the first RU **30** may include more modules than those described above, and some of the above modules may be omitted.

[0148] In the present disclosure, the front-haul handler module **1010** may include an uplink handler module **1012** and a downlink handler module **1014**. For example, the uplink handler module **1012** may refer to a module for transmitting and processing uplink data. For example, the downlink handler module **1014** may refer to a module for receiving and processing downlink data.

[0149] In one or more embodiments, the front-haul splitter **10** of the communication system **1040** may transmit identification information of the front-haul splitter **10** to at least one of the first DU **22**, the second DU **24**, or the first RU **30**. For example, the identification information of the front-haul splitter **10** may include at least one MAC address of the front-haul splitter **10**, or identification information associated with an IP of the front-haul splitter **10**.

[0150] In one or more embodiments, the first DU **22** of the communication system **1040** may transmit the first downlink IQ data **510** and the second DU **24** may transmit the second downlink IQ data **520** to the front-haul splitter **10** based on the identification information of the front-haul splitter **10**. For example, the first downlink IQ data **510** and the second downlink IQ data **520** may be transmitted to the first module **332** of the front-haul splitter **10**.

[0151] In one or more embodiments, the front-haul splitter **10** of the communication system **1040** may transmit the third downlink IQ data **530** to the first RU **30** based on at least one of the identification information of the front-haul splitter **10** or identification information of the first RU **30**. For example, the first module **332** of the front-haul splitter **10** may transmit the third downlink IQ data **530** to the downlink handler module **1014** of the first RU **30**. The third downlink IQ data **530** may be processed via the downlink handler module **1014**, the low-PHY module **1020**, and the RF module **1030** of the first RU **30**, and transmitted to a UE.

[0152] In one or more embodiments, the first RU **30** of the communication system **1040** may

transmit the first uplink IQ data **910** to the front-haul splitter **10** based on the identification information of the front-haul splitter **10**. For example, the uplink handler module **1012** of the first RU **30** may transmit the first uplink IQ data **910** to the second module **334** of the front-haul splitter **10**. The first uplink IQ data **910** may be data received from the UE and processed via the RF module **1030**, the low-PHY module **1020**, and the uplink handler module **1012**.

[0153] In one or more embodiments, the front-haul splitter **10** of the communication system **1040** may transmit the second uplink IQ data **920** to the first DU **22** and the third uplink IQ data **930** to the second DU **24** based on the identification information of the front-haul splitter **10**. For example, the second module **334** of the front-haul splitter **10** may transmit the second uplink IQ data **920** to the first DU **22** and the third uplink IQ data **930** to the second DU **24**.

[0154] FIG. **10B** is a diagram illustrating an in-DU embedded communication system **1050** including the DU pool **20** having the front-haul splitter **10** therein, according to one or more embodiments.

[0155] FIG. **10B** illustrates communication performed within the in-DU embedded communication system **1050** in which the front-haul splitter **10** is included as an entity or component in the DU pool **20**.

[0156] In one or more embodiments, the first DU **22** and the second DU **24** of the in-DU embedded communication system **1050** may transmit the first downlink IQ data **510** and the second downlink IQ data **520** to the front-haul splitter **10**. For example, the first downlink IQ data **510** and the second downlink IQ data **520** may be transmitted to the first module **332** of the front-haul splitter **10**.

[0157] In one or more embodiments, the front-haul splitter **10** of the in-DU embedded communication system **1050** may transmit the third downlink IQ data **530** to the first RU **30** based on at least one of identification information of the first DU **22**, identification information of the second DU **24**, or identification information of the first RU **30**. For example, the first module **332** of the front-haul splitter **10** may transmit the third downlink IQ data **530** to the downlink handler module **1014** of the first RU **30**. The third downlink IQ data **530** may be processed via the downlink handler module **1014**, the low-PHY module **1020**, and the RF module **1030** of the first RU **30**, and transmitted to a UE.

[0158] In one or more embodiments, the first RU **30** of the in-DU embedded communication system **1050** may transmit the first uplink IQ data **910** to the front-haul splitter **10** based on at least one of the identification information of the first DU **22**, the identification information of the second DU **24**, or the identification information of the first RU **30**. For example, the uplink handler module **1012** of the first RU **30** may transmit the first uplink IQ data **910** to the second module **334** of the front-haul splitter **10**. The first uplink IQ data **910** may be data received from the UE and processed via the RF module **1030**, the low-PHY module **1020**, and the uplink handler module **1012**.

[0159] In one or more embodiments, the front-haul splitter **10** of the in-DU embedded communication system **1050** may transmit the second uplink IQ data **920** to the first DU **22** and the third uplink IQ data **930** to the second DU **24**. For example, the second module **334** of the front-haul splitter **10** may respectively transmit the second uplink IQ data **920** and the third uplink IQ data **930** to the first DU **22** and the second DU **24**.

[0160] FIG. **10C** is a diagram illustrating an in-RU embedded communication system **1060** including the first RU **30** having the front-haul splitter **10** therein according to one or more embodiments.

[0161] FIG. **10C** illustrates communication when a front-haul splitter **10** is included as an entity or configuration included in an RU **30** within the in-RU embedded communication system **1060**.

[0162] In one or more embodiments, the first DU **22** and the second DU **24** of the in-RU embedded communication system **1060** may transmit the first downlink IQ data **510** and the second downlink IQ data **520** to the front-haul splitter **10** based on at least one of identification information of the first DU **22**, identification information of the second DU **24**, or identification information of the

first RU **30**. For example, the first downlink IQ data **510** and the second downlink IQ data **520** may be transmitted to the first module **332** of the front-haul splitter **10**.

[0163] In one or more embodiments, the front-haul splitter **10** of the in-RU embedded communication system **1060** may transmit the third downlink IQ data **530** to the first RU **30**. For example, the first module **332** of the front-haul splitter **10** may transmit the third downlink IQ data **530** to the downlink handler module **1014** of the first RU **30**. The third downlink IQ data **530** may be processed by the downlink handler module **1014**, the low-PHY module **1020**, and the RF module **1030** of the first RU **30**, and transmitted to a UE.

[0164] In one or more embodiments, the first RU **30** of the in-RU embedded communication system **1060** may transmit the first uplink IQ data **910** to the front-haul splitter **10**. For example, the uplink handler module **1012** of the first RU **30** may transmit the first uplink IQ data **910** to the second module **334** of the front-haul splitter **10**. The first uplink IQ data **910** may be data received from the UE and processed via the RF module **1030**, the low-PHY module **1020**, and the uplink handler module **1012**.

[0165] In one or more embodiments, the front-haul splitter **10** of the in-RU embedded communication system **1060** may transmit the second uplink IQ data **920** to the first DU **22** and the third uplink IQ data **930** to the second DU **24** based on at least one of the identification information of the first DU **22**, the identification information of the second DU **24**, or the identification information of the first RU **30**. For example, the second module **334** of the front-haul splitter **10** may transmit the second uplink IQ data **920** to the first DU **22** and the third uplink IQ data **930** to the second DU **24**.

[0166] FIG. **11** is a diagram illustrating a front-haul interface according to one or more embodiments.

[0167] From the lower-layer split perspective, an existing split point between the DU **120** and the RU **110** may be referred to as front-haul. In one or more embodiments, a front-haul interface between the DU **120** and the RU **110** may refer to an interface that allows IQ data to be transmitted.

[0168] In the lower-layer split, there may be several options for how to split functions of the PHY layer into high-PHY functions **1110**, which are functions of the PHY layer handled by the DU **120**, and low-PHY functions **1120**, which are functions of the PHY layer handled by the RU **110**. In the present disclosure, the front-haul interface may refer to an interface corresponding to Split Option 7.2 or Split Option 7.2x, as a non-limiting example.

[0169] For example, referring to FIG. **11**, the DU **120** may perform the high-PHY functions **1110** corresponding to coding, scrambling, modulation, and layer mapping, among the functions of the PHY layer. Furthermore, the RU **110** may perform the low-PHY functions **1120** corresponding to RE mapping, beamforming, inverse fast Fourier transform (IFFT), cyclic prefix (CP) addition, channel filter, interpolation, digital predistortion (DP D), and digital to analog conversion (DAC), among the functions of the PHY layer.

[0170] According to one or more embodiments, a front-haul splitter **10** between a DU and an RU may be provided to address problems occurring in existing communication systems.

[0171] In one or more embodiments, the front-haul splitter **10** may receive first downlink IQ data **510** from a first DU **22** and second downlink IQ data **520** from a second DU **24** connected to the front-haul splitter **10**.

[0172] In one or more embodiments, the front-haul splitter **10** may generate third downlink IQ data **530**, based on the first downlink IQ data **510** and the second downlink IQ data **520**.

[0173] In one or more embodiments, the front-haul splitter **10** may transmit the third downlink IQ data **530** to an RU **30** connected to the front-haul splitter **10**.

[0174] In the related art, because a front-haul interface does not support vDU scaling (connections between multi-vDUs and an RU), the processing capacity of a DU is determined by a maximum amount of data traffic coming into an RU. According to one or more embodiments, in a vDU scaling situation, the front-haul interface may support scalable connectivity between multi-vDUs

and an RU, thereby providing the effect of enabling vDU operation. In addition, the effect of solving problems related to the front-haul interface that occur when scale-out is performed may be provided.

[0175] According to one or more embodiments, use of the front-haul splitter **10** may enable communication between multi-DUs and an RU, which is not possible with an existing front-haul interface.

[0176] In one or more embodiments, the third downlink IQ data **530** may correspond to a value of a vector sum of the first downlink IQ data **510** and the second downlink IQ data **520**.

[0177] In one or more embodiments, the first downlink IQ data **510** may correspond to downlink data.

[0178] In one or more embodiments, the second downlink IQ data **520** may correspond to the downlink data, or may be a value of (0, 0).

[0179] From an RU perspective, when the RU is connected to N DUs, it will receive N pieces of IQ data, each representing one RE, when receiving downlink data. In addition, REs transmitted by a DU represent various physical channels, and there are various ways to represent the physical channels as IQ data. According to one or more embodiments, an operation method of the front-haul splitter **10** applicable to any type of downlink data may be provided.

[0180] In addition, according to one or more embodiments, the front-haul splitter **10** may generate uplink IQ data without identifying a type of downlink data to be transmitted, thereby providing the effect of quickly processing data.

[0181] In one or more embodiments, the front-haul splitter **10** may be included in the DU pool **20** including the first DU **22** and the second DU **24**, or may be included in the first RU **30**.

[0182] In one or more embodiments, the front-haul splitter **10** may transmit identification information of the front-haul splitter **10** to at least one of the first DU **22**, the second DU **24**, or the first RU **30**.

[0183] In one or more embodiments, the identification information of the front-haul splitter **10** may include at least one MAC address of the front-haul splitter **10**, or identification information associated with an IP of the front-haul splitter **10**.

[0184] In one or more embodiments, the first downlink IQ data **510** and the second downlink IQ data **520** may be received based on the identification information of the front-haul splitter **10**.

[0185] In one or more embodiments, the third downlink IQ data **530** may be transmitted based on the identification information of the front-haul splitter **10**.

[0186] According to one or more embodiments, the front-haul splitter **10** may provide an effect whereby flexible implementation thereof is possible in an independent form, a form included in an RU, a form included in a DU pool, etc., depending on the needs of a network environment, a user, etc.

[0187] In one or more embodiments, the front-haul splitter **10** may receive first uplink IQ data **910** from the first RU **30**.

[0188] In one or more embodiments, the front-haul splitter **10** may identify second uplink IQ data **920** based on at least one of the first uplink IQ data **910**, information about a target DU, or the number of DUs connected to the front-haul splitter **10**.

[0189] In one or more embodiments, the front-haul splitter **10** may transmit the second uplink IQ data **920** to the first DU **22**.

[0190] According to one or more embodiments, an effect may be provided which enables all vDUs including a new DU (e.g., a vDU), connected to an RU, to communicate with the RU during vDU scale-in and scale-out.

[0191] According to one or more embodiments, an effect of enabling seamless scalable virtual DU operation may be provided.

[0192] In one or more embodiments, the front-haul splitter **10** may transmit the third uplink IQ data **930** to the second DU **24**.

[0193] In one or more embodiments, the second uplink IQ data **920** and the third uplink IQ data **930** may each include the same value as the first uplink IQ data **910**.

[0194] In one or more embodiments, the second uplink IQ data **920** and the third uplink IQ data **930** may be data obtained by duplicating the first uplink IQ data **910** based on the number of DUs connected to the front-haul splitter **10**.

[0195] When N DUs are connected to an RU, it is difficult for the RU to identify to which DU it should transmit an RE for uplink data that currently needs to be transmitted. However, according to one or more embodiments of the present disclosure, the front-haul splitter **10** may generate uplink IQ data by taking into account the characteristics of the MAC layer, thereby providing an effect of efficiently transmitting data.

[0196] Furthermore, according to one or more embodiments, the front-haul splitter **10** may generate uplink IQ data without identifying a type of uplink data to be transmitted, thereby providing the effect of quickly processing data.

[0197] Also, in the case of a PRACH, only one of the N DUs needs to process a PRACH, so even when all the DUs receive PRACHs only one DU needs to perform a PRACH procedure. Thus, according to one or more embodiments, an operation method of the front-haul splitter **10** applicable to any type of uplink data may be provided.

[0198] In one or more embodiments, the front-haul splitter **10** may receive scheduling information from the at least one first DU **22**, or the second DU **24**.

[0199] In one or more embodiments, the front-haul splitter **10** may identify information about a target DU based on the scheduling information.

[0200] In one or more embodiments, based on the information about the target DU, the first DU **22** may be identified as a target DU for transmitting the second uplink IQ data **920** including the same value as the first uplink IQ data **910**.

[0201] In one or more embodiments, the first uplink IQ data **910** may be received based on the identification information of the front-haul splitter **10**.

[0202] In one or more embodiments, the second uplink IQ data **920** and the third uplink IQ data **930** may be received based on the identification information of the front-haul splitter **10**.

[0203] In one or more embodiments, the identification information of the front-haul splitter **10** may include at least one MAC address of the front-haul splitter **10**, or identification information associated with an IP of the front-haul splitter **10**.

[0204] In one or more embodiments, the first downlink IQ data **510** and the second downlink IQ data **520** may be received based on time resource allocation information.

[0205] In one or more embodiments, a front-haul splitter **10** operating in a wireless communication system may include a transceiver **310**, and at least one processor **320** coupled to the transceiver **310** to operate therewith.

[0206] In one or more embodiments, the at least one processor **320** may be configured to control the transceiver **310** to receive first downlink IQ data **510** from a first DU **22** and second downlink IQ data **520** from a second DU **24** connected to the front-haul splitter **10**.

[0207] In one or more embodiments, the at least one processor **320** may be configured to generate third downlink IQ data **530**, based on the first downlink IQ data **510** and the second downlink IQ data **520**.

[0208] In one or more embodiments, the at least one processor **320** may control the transceiver **310** to transmit the third downlink IQ data **530** to an RU **30** connected to the front-haul splitter **10**.

[0209] In one or more embodiments, the third downlink IQ data **530** may correspond to a value of a vector sum of the first downlink IQ data **510** and the second downlink IQ data **520**.

[0210] In one or more embodiments, the first downlink IQ data **510** may correspond to downlink data.

[0211] In one or more embodiments, the second downlink IQ data **520** may correspond to the downlink data, or may be a value of (0, 0).

[0212] In one or more embodiments, the at least one processor **320** may be configured to control the transceiver **310** to transmit identification information of the front-haul splitter **10** to at least one first DU **22**, the second DU **24**, or the first RU **30**.

[0213] In one or more embodiments, the identification information of the front-haul splitter **10** may include at least one MAC address of the front-haul splitter **10**, or identification information associated with an IP of the front-haul splitter **10**.

[0214] In one or more embodiments, the first downlink IQ data **510** and the second downlink IQ data **520** may be received based on the identification information of the front-haul splitter **10**.

[0215] In one or more embodiments, the third downlink IQ data **530** may be transmitted based on the identification information of the front-haul splitter **10**.

[0216] In one or more embodiments, the front-haul splitter **10** may be included in a DU pool **20** including the first DU **22** and the second DU **24**, or may be included in the first RU **30**.

[0217] In one or more embodiments, the at least one processor **320** may be configured to control the transceiver **310** to receive first uplink IQ data **910** from the first RU **30**.

[0218] In one or more embodiments, the at least one processor **320** may be configured to identify second uplink IQ data **920** based on at least one of the first uplink IQ data **910**, information about a target DU, or the number of DUs connected to the front-haul splitter **10**.

[0219] In one or more embodiments, the at least one processor **320** may be configured to control the transceiver **310** to transmit the second uplink IQ data **920** to the first DU **22**.

[0220] In one or more embodiments, the at least one processor **320** may be configured to control the transceiver **310** to transmit the second uplink IQ data **920** to the first DU **22**.

[0221] In one or more embodiments, the second uplink IQ data **920** and the third uplink IQ data **930** may each include the same value as the first uplink IQ data **910**.

[0222] In one or more embodiments, the second uplink IQ data **920** and the third uplink IQ data **930** may be data obtained by duplicating the first uplink IQ data **910** based on the number of DUs connected to the front-haul splitter **10**.

[0223] In one or more embodiments, the at least one processor **320** may be configured to control the transceiver **310** to receive scheduling information from the at least one first DU **22** or the second DU **24**.

[0224] In one or more embodiments, the at least one processor **320** may be configured to identify information about a target DU based on the scheduling information.

[0225] In one or more embodiments, based on the information about the target DU, the first DU **22** may be identified as a target DU for transmitting the second uplink IQ data **920** including the same value as the first uplink IQ data **910**.

[0226] In one or more embodiments, the first uplink IQ data **910** may be received based on the identification information of the front-haul splitter **10**.

[0227] In one or more embodiments, the second uplink IQ data **920** and the third uplink IQ data **930** may be transmitted based on the identification information of the front-haul splitter **10**.

[0228] In one or more embodiments, the identification information of the front-haul splitter **10** may include at least one MAC address of the front-haul splitter **10**, or identification information associated with an IP of the front-haul splitter **10**.

[0229] In one or more embodiments, a computer-readable recording medium having recorded thereon a program for performing the operation method of the front-haul splitter **10** on a computer may be provided.

[0230] A machine-readable storage medium may be provided in the form of a non-transitory storage medium. In this regard, the term ‘non-transitory storage medium’ only means that the storage medium does not include a signal (e.g., an electromagnetic wave) and is a tangible device, and the term does not differentiate between where data is semi-permanently stored in the storage medium and where the data is temporarily stored in the storage medium. For example, the ‘non-transitory storage medium’ may include a buffer for temporarily storing data.

[0231] According to one or more embodiments, methods according to various embodiments set forth herein may be included in a computer program product when provided. The computer program product may be traded, as a product, between a seller and a buyer. The computer program product may be distributed in the form of a machine-readable storage medium (e.g., CD-ROM) or distributed (e.g., downloaded or uploaded) on-line via an application store or directly between two user devices (e.g., smartphones). For online distribution, at least a part of the computer program product (e.g., a downloadable app) may be at least transiently stored or temporally generated in a machine-readable storage medium such as a memory of a server of a manufacturer, a server of an application store, or a relay server.

Claims

1. An operation method of a front-haul splitter in a wireless communication system, the operation method comprising: receiving first downlink in-phase and quadrature (IQ) data from a first distributed unit (DU) connected to the front-haul splitter and second downlink IQ data from a second DU connected to the front-haul splitter; generating third downlink IQ data, based on the first downlink IQ data and the second downlink IQ data; and transmitting the third downlink IQ data to a radio unit (RU) connected to the front-haul splitter.
2. The operation method of claim 1, wherein the third downlink IQ data corresponds to a vector sum of the first downlink IQ data and the second downlink IQ data, wherein the first downlink IQ data corresponds to downlink data, and wherein the second downlink IQ data corresponds to the downlink data, or is a value of (0, 0).
3. The operation method of claim 1, further comprising: transmitting identification information of the front-haul splitter to at least one of the first DU, the second DU, or the RU, wherein the identification information of the front-haul splitter comprises at least one medium access control (MAC) address of the front-haul splitter, or information associated with an Internet Protocol (IP) of the front-haul splitter.
4. The operation method of claim 3, wherein the first downlink IQ data and the second downlink IQ data are received based on the identification information of the front-haul splitter, and wherein the third downlink IQ data is transmitted based on the identification information of the front-haul splitter.
5. The operation method of claim 1, wherein the front-haul splitter is in a DU pool including the first DU and the second DU, or is in the RU.
6. The operation method of claim 3, further comprising: receiving first uplink IQ data from the RU; identifying second uplink IQ data based on at least one of the first uplink IQ data, information about a target DU, or a number of DUs connected to the front-haul splitter; and transmitting the second uplink IQ data to the first DU.
7. The operation method of claim 6, further comprising: transmitting third uplink IQ data to the second DU, wherein the second uplink IQ data and the third uplink IQ data each comprise a same value as the first uplink IQ data, and wherein the second uplink IQ data and the third uplink IQ data are obtained by duplicating the first uplink IQ data based on the number of DUs connected to the front-haul splitter.
8. The operation method of claim 6, further comprising: receiving scheduling information from at least one of the first DU or the second DU; and identifying the information about the target DU based on the scheduling information, wherein, based on the information about the target DU, the first DU is identified as the target DU for transmitting the second uplink IQ data comprising a same value as the first uplink IQ data.
9. The operation method of claim 7, wherein the first uplink IQ data is received based on the identification information of the front-haul splitter, wherein the second uplink IQ data and the third uplink IQ data are transmitted based on the identification information of the front-haul splitter, and

wherein the identification information of the front-haul splitter comprises the at least one MAC address of the front-haul splitter, or the information associated with the IP of the front-haul splitter.

10. The operation method of claim 1, wherein the first downlink IQ data and the second downlink IQ data are received based on time resource allocation information.

11. A front-haul splitter operating in a wireless communication system, the front-haul splitter comprising: a transceiver; at least one processor coupled to the transceiver to operate therewith; and memory storing instructions that, when executed by the at least one processor, cause the at least one processor to: control the transceiver to receive first downlink in-phase and quadrature (IQ) data from a first distributed unit (DU) connected to the front-haul splitter and second downlink IQ data from a second DU connected to the front-haul splitter; generate third downlink IQ data, based on the first downlink IQ data and the second downlink IQ data; and control the transceiver to transmit the third downlink IQ data to a radio unit (RU) connected to the front-haul splitter.

12. The front-haul splitter of claim 11, wherein the third downlink IQ data corresponds to a vector sum of the first downlink IQ data and the second downlink IQ data, wherein the first downlink IQ data corresponds to downlink data, and wherein the second downlink IQ data corresponds to the downlink data, or is a value of (0, 0).

13. The front-haul splitter of claim 11, wherein the instructions further cause the at least one processor to: control the transceiver to transmit identification information of the front-haul splitter to at least one of the first DU, the second DU, or the RU, wherein the identification information of the front-haul splitter comprises at least one medium access control (MAC) address of the front-haul splitter, or information associated with an Internet Protocol (IP) of the front-haul splitter.

14. The front-haul splitter of claim 13, wherein the first downlink IQ data and the second downlink IQ data are received based on the identification information of the front-haul splitter, and wherein the third downlink IQ data is transmitted based on the identification information of the front-haul splitter.

15. The front-haul splitter of claim 11, wherein the front-haul splitter is in a DU pool comprising the first DU and the second DU, or is in the RU.

16. The front-haul splitter of claim 13, wherein the instructions further cause the at least one processor to: control the transceiver to receive first uplink IQ data from the RU; identify second uplink IQ data based on at least one of the first uplink IQ data, information about a target DU, or a number of DUs connected to the front-haul splitter; and control the transceiver to transmit the second uplink IQ data to the first DU.

17. The front-haul splitter of claim 16, wherein the instructions further cause the at least one processor to: control the transceiver to transmit third uplink IQ data to the second DU, wherein the second uplink IQ data and the third uplink IQ data each comprise a same value as the first uplink IQ data, and wherein the second uplink IQ data and the third uplink IQ data are obtained by duplicating the first uplink IQ data based on the number of DUs connected to the front-haul splitter.

18. The front-haul splitter of claim 16, wherein the instructions further cause the at least one processor to: control the transceiver to receive scheduling information from at least one of the first DU or the second DU; and identify the information about the target DU based on the scheduling information, wherein, based on the information about the target DU, the first DU is identified as the target DU for transmitting the second uplink IQ data comprising a same value as the first uplink IQ data.

19. The front-haul splitter of claim 17, wherein the first uplink IQ data is received based on the identification information of the front-haul splitter, wherein the second uplink IQ data and the third uplink IQ data are transmitted based on the identification information of the front-haul splitter, and wherein the identification information of the front-haul splitter comprises the at least one MAC address of the front-haul splitter, or the information associated with the IP of the front-haul splitter.

20. The front-haul splitter of claim 11, wherein the first downlink IQ data and the second downlink IQ data are received based on time resource allocation information.

