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Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a),(b) or (b-bis)

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Document details: Country/Office: US

Filing date: 14 Apr 2023 (14.04.2023)

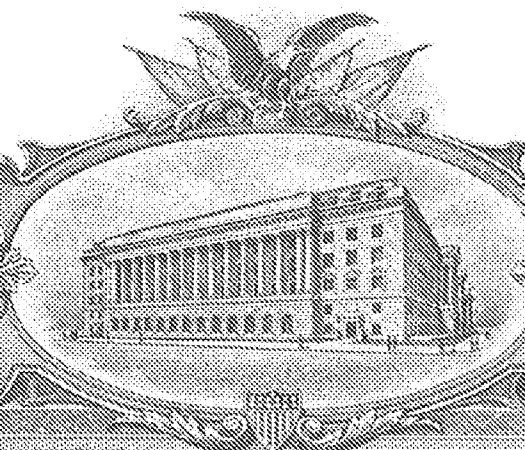
Application number: 63496132

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THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

April 15, 2024

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE UNDER 35 USC 111.

APPLICATION NUMBER: 63/496,132

FILING DATE: *April 14, 2023*

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS *US63/496,132*



Certified by

Kathi

Under Secretary of Commerce
for Intellectual Property
and Director of the United States
Patent and Trademark Office

TRANSMITTAL FOR POWER OF ATTORNEY TO ONE OR MORE REGISTERED PRACTITIONERS

NOTE: This form is to be submitted with the Power of Attorney by Applicant form (PTO/AIA/82B) to identify the application to which the Power of Attorney is directed, in accordance with 37 CFR 1.5, unless the application number and filing date are identified in the Power of Attorney by Applicant form. If neither form PTO/AIA/82A nor form PTO/AIA/82B identifies the application to which the Power of Attorney is directed, the Power of Attorney will not be recognized in the application.

Application Number	New Application
Filing Date	April 14, 2023
First Named Inventor	Roghayeh JODA
Title	RAN NETWORK FUNCTION PLACEMENT WITH CARRIER AGGREGATION IN CLOUD NETWORK USING ML ALGORITHM
Art Unit	NYK
Examiner Name	NYK
Attorney Docket Number	1557-2064P (P108176US01)

SIGNATURE of Applicant or Patent Practitioner

Signature	/Alan M. Weisberg/	Date (Optional)	
Name	Alan M. Weisberg	Registration Number	43982
Title (if Applicant is a juristic entity)			
Applicant Name (if Applicant is a juristic entity)			

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4(d) for signature requirements and certifications. If more than one applicant, use multiple forms.



*Total of (1) forms are submitted.

This collection of information is required by 37 CFR 1.131, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

**POWER OF ATTORNEY TO PROSECUTE APPLICATIONS BEFORE THE
UNITED STATES PATENT & TRADEMARK OFFICE**

I hereby revoke all previous power of attorney given in the application identified in the attached transmittal letter and appoint the Practitioners named below:

<u>Name</u>	<u>Registration Number</u>
Alan M. WEISBERG	Registration No: 43,982
John CHRISTOPHER	Registration No: 37,596

as attorney(s) or agent(s) to represent the undersigned before the United States Patent and Trademark Office (USPTO) in connection with the application referenced in the attached transmittal letter. This Power of Attorney does not give the right to the above-listed practitioners to grant supplemental Powers of Attorney.

Please change the correspondence address for the application identified in the attached transmittal letter to:

The address associated with Customer Number:

Customer No: 31292
Alan M. Weisberg
Christopher & Weisberg, P.A.
1232 North University Drive
Plantation, FL 33322

Direct all telephone calls to: Alan M. Weisberg
(954) 828-1488

Assignee Name and Address: Telefonaktiebolaget LM Ericsson (Publ)
SE-164 83 Stockholm, Sweden

I hereby certify that I am the Applicant as assignee or person to who the inventor is under an obligation to assign.

This Power of Attorney shall be valid for new application filings for a five (5) year period from the date of execution below and in perpetuity for applications once filed, unless earlier revoked by Assignee.

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee.

Signature



Date

27 June, 2019

Name

Gabriele Mohsler

Telephone

+492407575681

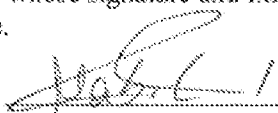
Title

Vice President, Patent Development

SIGNATURE of Assignee of Record

The individual whose signature and title is supplied below is authorized to act on behalf of the assignee.

Signature



Date

20 June, 2019

Name

Nabil Ayoub

Telephone

+46107142985

Title

Director, Patent Unit Kista RAN2

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	1557-2064P (P108176US01)
		Application Number	
Title of Invention	RAN NETWORK FUNCTION PLACEMENT WITH CARRIER AGGREGATION IN CLOUD NETWORK USING ML ALGORITHM		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2:

☐	Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)
--------------------------	---

Inventor Information:

Inventor	1	Remove		
Legal Name				
Prefix	Given Name	Middle Name	Family Name	Suffix
	Roghayeh		JODA	
Residence Information (Select One)				US Residency • Non US Residency Active US Military Service
City	Ottawa	Country of Residence ⁱ	CA	
Mailing Address of Inventor:				
Address 1	#607, 225 Wilbrod			
Address 2				
City	Ottawa	State/Province	ON	
Postal Code	K1N 6L9	Country ⁱ	CA	
Inventor	2	Remove		
Legal Name				
Prefix	Given Name	Middle Name	Family Name	Suffix
	Sima		NASERI	
Residence Information (Select One)				US Residency ● Non US Residency Active US Military Service
City	Ottawa	Country of Residence ⁱ	CA	
Mailing Address of Inventor:				
Address 1	1300 McWatters Rd, Apt 1612			
Address 2				
City	Ottawa	State/Province	ON	
Postal Code	K2C 3M5	Country ⁱ	CA	
Inventor	3	Remove		
Legal Name				

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	1557-2064P (P108176US01)
		Application Number	
Title of Invention	RAN NETWORK FUNCTION PLACEMENT WITH CARRIER AGGREGATION IN CLOUD NETWORK USING ML ALGORITHM		

Prefix	Given Name	Middle Name	Family Name	Suffix
	Mona		HASHEMI	
Residence Information (Select One) US Residency ☒ Non US Residency Active US Military Service				
City	Ottawa	Country of Residence ⁱ	CA	

Mailing Address of Inventor:

Address 1	203 Catherine Street, #711			
Address 2				
City	Ottawa	State/Province	ON	
Postal Code	K2P1J5	Country ⁱ	CA	
Inventor	4	Remove		

Legal Name

Prefix	Given Name	Middle Name	Family Name	Suffix
	Christopher		RICHARDS	
Residence Information (Select One) US Residency ☒ Non US Residency Active US Military Service				
City	Ottawa	Country of Residence ⁱ	CA	

Mailing Address of Inventor:

Address 1	4 Mutchmor Road			
Address 2				
City	Ottawa	State/Province	ON	
Postal Code	K1S 1L5	Country ⁱ	CA	
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button.				

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).				
☐ An Address is being provided for the correspondence information of this application.				
Customer Number	31292			
Email Address	ptomail@cwiplaw.com	Add Email	Remove Email	
Email Address	docketing@cpaglobal.com	Add Email	Remove Email	

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	1557-2064P (P108176US01)
		Application Number	
Title of Invention	RAN NETWORK FUNCTION PLACEMENT WITH CARRIER AGGREGATION IN CLOUD NETWORK USING ML ALGORITHM		

Application Information:

Title of the Invention	RAN NETWORK FUNCTION PLACEMENT WITH CARRIER AGGREGATION IN CLOUD NETWORK USING ML ALGORITHM		
Attorney Docket Number	1557-2064P (P108176US01)	Small Entity Status Claimed	☐
Application Type	Provisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)		Suggested Figure for Publication (if any)	

Filing By Reference:

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐ Request Not to Publish. I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.			
Please Select One:	☒ Customer Number	US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)
Customer Number	31292		

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	1557-2064P (P108176US01)
		Application Number	
Title of Invention	RAN NETWORK FUNCTION PLACEMENT WITH CARRIER AGGREGATION IN CLOUD NETWORK USING ML ALGORITHM		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, 365(c), or 386(c) or indicate National Stage entry from a PCT application. Providing benefit claim information in the Application Data Sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

When referring to the current application, please leave the "Application Number" field blank.

Prior Application Status		Remove	
Application Number	Continuity Type	Prior Application Number	Filing or 371(c) Date (YYYY-MM-DD)
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the Add button.			Add

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55. When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX)ⁱ the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(i)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

Application Number	Country ⁱ	Filing Date (YYYY-MM-DD)	Access Code ⁱ (if applicable)	Remove
Additional Foreign Priority Data may be generated within this form by selecting the Add button.				Add

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013. ☐ NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	1557-2064P (P108176US01)
		Application Number	
Title of Invention	RAN NETWORK FUNCTION PLACEMENT WITH CARRIER AGGREGATION IN CLOUD NETWORK USING ML ALGORITHM		

Authorization or Opt-Out of Authorization to Permit Access:

When this Application Data Sheet is properly signed and filed with the application, applicant has provided written authority to permit a participating foreign intellectual property (IP) office access to the instant application-as-filed (see paragraph A in subsection 1 below) and the European Patent Office (EPO) access to any search results from the instant application (see paragraph B in subsection 1 below).

Should applicant choose not to provide an authorization identified in subsection 1 below, applicant **must opt-out** of the authorization by checking the corresponding box A or B or both in subsection 2 below.

NOTE: This section of the Application Data Sheet is **ONLY** reviewed and processed with the **INITIAL** filing of an application. After the initial filing of an application, an Application Data Sheet cannot be used to provide or rescind authorization for access by a foreign IP office(s). Instead, Form PTO/SB/39 or PTO/SB/69 must be used as appropriate.

1. Authorization to Permit Access by a Foreign Intellectual Property Office(s)

A. Priority Document Exchange (PDX) - Unless box A in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO), the World Intellectual Property Organization (WIPO), and any other foreign intellectual property office participating with the USPTO in a bilateral or multilateral priority document exchange agreement in which a foreign application claiming priority to the instant patent application is filed, access to: (1) the instant patent application-as-filed and its related bibliographic data, (2) any foreign or domestic application to which priority or benefit is claimed by the instant application and its related bibliographic data, and (3) the date of filing of this Authorization. See 37 CFR 1.14(h)(1).

B. Search Results from U.S. Application to EPO - Unless box B in subsection 2 (opt-out of authorization) is checked, the undersigned hereby **grants the USPTO authority** to provide the EPO access to the bibliographic data and search results from the instant patent application when a European patent application claiming priority to the instant patent application is filed. See 37 CFR 1.14(h)(2).

The applicant is reminded that the EPO's Rule 141(1) EPC (European Patent Convention) requires applicants to submit a copy of search results from the instant application without delay in a European patent application that claims priority to the instant application.

2. Opt-Out of Authorizations to Permit Access by a Foreign Intellectual Property Office(s)

A. Applicant **DOES NOT** authorize the USPTO to permit a participating foreign IP office access to the instant application-as-filed. If this box is checked, the USPTO will not be providing a participating foreign IP office with any documents and information identified in subsection 1A above.

☐

B. Applicant **DOES NOT** authorize the USPTO to transmit to the EPO any search results from the instant patent application. If this box is checked, the USPTO will not be providing the EPO with search results from the instant application.

☐

NOTE: Once the application has published or is otherwise publicly available, the USPTO may provide access to the application in accordance with 37 CFR 1.14.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	1557-2064P (P108176US01)
		Application Number	
Title of Invention	RAN NETWORK FUNCTION PLACEMENT WITH CARRIER AGGREGATION IN CLOUD NETWORK USING ML ALGORITHM		

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Applicant	1	Remove
If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section. Clear		
Assignee	Legal Representative under 35 U.S.C. 117	Joint Inventor
☒ Person to whom the inventor is obligated to assign.		☐ Person who shows sufficient proprietary interest
If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:		
Name of the Deceased or Legally Incapacitated Inventor:		
If the Applicant is an Organization check here. ☒		
Organization Name	Telefonaktiebolaget LM Ericsson (publ)	
Mailing Address Information For Applicant:		
Address 1	SE 164-83	
Address 2		
City	Stockholm	State/Province
Country	SE	Postal Code
Phone Number		Fax Number
Email Address		
Additional Applicant Data may be generated within this form by selecting the Add button. Add		

Assignee Information including Non-Applicant Assignee Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	1557-2064P (P108176US01)
		Application Number	
Title of Invention	RAN NETWORK FUNCTION PLACEMENT WITH CARRIER AGGREGATION IN CLOUD NETWORK USING ML ALGORITHM		

Assignee	1
----------	---

Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.

[Remove](#)If the Assignee or Non-Applicant Assignee is an Organization check here. ☐

Prefix	Given Name	Middle Name	Family Name	Suffix

Mailing Address Information For Assignee including Non-Applicant Assignee:

Address 1				
Address 2				
City		State/Province		
Country i		Postal Code		
Phone Number		Fax Number		
Email Address				

Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button.

[Add](#)**Signature:**[Remove](#)

NOTE: This Application Data Sheet must be signed in accordance with 37 CFR 1.33(b). However, if this Application Data Sheet is submitted with the **INITIAL** filing of the application and either box A or B is not checked in subsection 2 of the "Authorization or Opt-Out of Authorization to Permit Access" section, then this form must also be signed in accordance with 37 CFR 1.14(c).

This Application Data Sheet **must** be signed by a patent practitioner if one or more of the applicants is a **juristic entity** (e.g., corporation or association). If the applicant is two or more joint inventors, this form must be signed by a patent practitioner, **all** joint inventors who are the applicant, or one or more joint inventor-applicants who have been given power of attorney (e.g., see USPTO Form PTO/AIA/81) on behalf of **all** joint inventor-applicants.

See 37 CFR 1.4(d) for the manner of making signatures and certifications.

Signature	/Alan M. Weisberg/		Date (YYYY-MM-DD)	2023-04-14	
First Name	Alan M.	Last Name	Weisberg	Registration Number	43982

Additional Signature may be generated within this form by selecting the Add button.

[Add](#)

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	1557-2064P (P108176US01)
		Application Number	
Title of Invention	RAN NETWORK FUNCTION PLACEMENT WITH CARRIER AGGREGATION IN CLOUD NETWORK USING ML ALGORITHM		

This collection of information is required by 37 CFR 1.76. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.



ELECTRONIC ACKNOWLEDGEMENT RECEIPT

APPLICATION #
63/496,132

RECEIPT DATE / TIME
04/14/2023 02:10:50 PM ET

ATTORNEY DOCKET #
1557-2064P (P108176US01)

Title of Invention

RAN NETWORK FUNCTION PLACEMENT WITH CARRIER AGGREGATION IN CLOUD NETWORK
USING ML ALGORITHM

Application Information

APPLICATION TYPE Utility - Provisional Application under
35 USC 111(b)

PATENT # -

CONFIRMATION # 1091

FILED BY Lillian Pillitteri

PATENT CENTER # 61922325

FILING DATE -

CUSTOMER # 31292

FIRST NAMED INVENTOR Roghayeh JODA

CORRESPONDENCE ADDRESS -

AUTHORIZED BY Alan Weisberg

Documents

TOTAL DOCUMENTS: 3

DOCUMENT	PAGES	DESCRIPTION	SIZE (KB)
P108176US01_2023-04-14_APPL_ADS.pdf	9	Application Data Sheet	2174 KB
P108176US01_2023-04-14_APPL_POA.pdf	3	Power of Attorney	527 KB
P108176US01_2023-04-14_APPL_Specification.pdf	34	Specification	841 KB

Digest

DOCUMENT	MESSAGE DIGEST(SHA-512)
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P108176US01_2023-04-14_APPL_ADS.pdf	F4E87493F353AAEDB309C0F298AEB1D5BB1BCFE0285B89C5BD1173F7ADCCDA8C3556BC918E7B652AA0E9C9AE579168C83CFBAC9F44E7BC0FC8B3888BC6E6363F
P108176US01_2023-04-14_APPL_POA.pdf	FE2CA9C8204010F2BFAE3A0798D986F0F4DFC96A995F8080E9E94D409AB84E48F2C48BC49CE968E8211B911E8D09B9E56D4C256ADE80B5BF38DC1AC0C8827EF5
P108176US01_2023-04-14_APPL_Specification.pdf	35A3BD2FD868603A429CAAF17FA20DB2935963B9B481AC5EBE8C05A8930CE0AB8B7B39FCCB80827317D0B9F491A2104DEDEF325F4818294F67B320751F8AF4EA

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UNITED STATES PROVISIONAL PATENT APPLICATION

TITLE: RAN NETWORK FUNCTION PLACEMENT WITH CARRIER
AGGREGATION IN CLOUD NETWORK USING ML ALGORITHM

Inventors:

Roghayeh JODA
Sima NASERI
Mona HASHEMI
Christopher RICHARDS

CHRISTOPHER & WEISBERG, P.A.
1232 N. University Drive
Plantation, FL 33322
Telephone: (954) 828-1488
Facsimile: (954) 828-9122

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FIELD

The present disclosure relates to wireless communications, and in particular, to placement of network functions associated with carrier aggregation using machine learning.

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INTRODUCTION

The Open Radio Access Network (O-RAN) alliance has developed and is developing O-RAN standards and/or specifications for wireless communication systems which may comprise O-RAN based mobile networks. Such systems provide, among other features, broadband communication between network nodes (NNs), such as base stations, and mobile wireless devices (WD), as well as communication between network nodes and between WDs.

Further, O-RAN includes technology which is based on disaggregation, virtualization, open interface, automation and intelligence. O-RAN provides flexibility, scalability, robustness, and cost efficiency but also generates unprecedented new revenue possibilities for the network operators and Communication Service Providers (CSPs). Disaggregation in O-RAN makes the Network Functions (NFs) beyond the Radio Unit (RU) be distributed into Centralized Units (CUs) and Distributed Units (DUs) based on a specified network functional split, e.g., as shown in FIG. 1. Virtualization helps the CUs and DUs on the O-RAN Cloud (O-Cloud) nodes run efficiently by creating Virtualized Network Functions (VNFs) or Containerized Network Functions (CNFs).

Finding the best O-Cloud nodes to host the VNFs of each DU and CU while satisfying the delay demand of the UEs is currently being studied. For example, the latency aware DU-CU placement in the packet-based networks may be considered such as to formulate a problem as a Mixed Integer Linear Problem (MILP). A Deep Reinforcement Learning (DRL) algorithm for the problem of joint DU and CU placement and RU association may be used. Further, actor-critic learning algorithms may be used to minimize the energy consumption while satisfying the delay targets of the users.

In addition, Carrier Aggregation (CA) techniques have been introduced in LTE-advanced and used in 5G wireless mobile networks, in which Component Carriers (CCs) are aggregated to improve the throughput of the WDs. In CA, each WD is assigned to a Primary Cell (PCell) and this PCell always is active for that specific WD.

However, the Secondary Cells (SCells) can be activated or deactivated during the time that WD is connected to the network. Each cell has its own Medium Access Control (MAC) and Radio Link Control (RLC) while Radio Resource Control (RRC) and other upper layers are the same for the different cells. Since SCells are dynamically activated or deactivated for different users, it is beneficial to leverage the disaggregation and virtualization aspects of cloud based RANs such as O-RAN to reduce the cost of network operators.

In current communication network technologies, the NFs of the DUs for each CC run in a fixed node. If the DU for all CCs runs in one processing node, this leads to a long delay from the DU to the WDs. The delay consists of propagation, processing, transmission, and scheduling/queuing. Further, optimizing the placement of CCs in DU NF instances, and DU NF instances in cloud nodes is an extremely complex and time intensive task.

SUMMARY

Some embodiments advantageously provide methods, systems, and apparatuses for RAN network function placement with carrier aggregation in cloud network(s) using machine learning processes. In some embodiments, by exploiting the virtualization technique in a cloud network, the network nodes (e.g., optimum processing nodes) in the cloud network may be determined to run the network functions of DUs for different CCs.

In some other embodiments, a Deep Q-Network (DQN) based Deep Reinforcement Learning (DRL) scheme is used to minimize end-to-end delay (e.g., of the users) and the number of network nodes (e.g., O-Cloud nodes) used to place the DU NFs, while satisfying the delay target of users. That is, an ML solution for the problem of DU network function placement with carrier aggregation in O-RAN is described.

In some embodiments, a DRL model that minimizes the WD user plane traffic delay is used when using carrier aggregation in a RAN, while at the same time minimizing the number of placed DU NFs so that a target WD delay is satisfied. In some other embodiments, constraints include RAN NF (CU, DU and RU) compute resources and inter NF communication link bandwidth.

In some other embodiments, a method is described and may include one or more of the following steps:

- Modeling a communication network (i.e., network).

- Modeling an end-to-end (E2E) delay in the communication network. Parameters can be obtained from real data collected in the network (e.g., E2E WD delay today).
- Including (e.g., in the modeling) the processing, transmission, propagation, and queuing delay which is from CU to the WD throughout the Midhaul (MH), IDU (Inter DU) and FH (Fronthaul).
- Defining the WD Centric DU network function Placement with Carrier Aggregation optimization problem.
- Using a weighted sum of the delay and the number of used network nodes (e.g., cloud nodes) to host DU network functions for the CCs.
- Applying Deep Reinforcement Learning-based DU Placement with CA (DUPCA) (e.g., to the modeling).
- Using a DRL algorithm to minimize the number of placed DUs while satisfying the delay target for each user. This is done by choosing the proper DU placement for each CC.

Real world input data from NNs (e.g., RAN cloud nodes and NFs) and/or constraints such as to produce model generation and a solution to a placement problem such as an OAM system to configure the instantiation RAN NFs of CCs in a cloud network. The model can be dynamically re-generated periodically as input parameters and constraints change over time.

One or more embodiments minimize end to end delay from the CU to the end WD in a network (e.g., cloud network) while considering the number of NNs (e.g., cloud nodes) to be used to instantiate the DU NFs for the CCs. One or more embodiments enables (e.g., determine) an optimal number of DU NFs to be instantiated on NNs (e.g., O-Cloud nodes) while satisfying the end user quality of service expectations, such as E2E delay. This optimization also leads to significant cost savings for the network operator such as:

- Automating the DU placement operations. This is traditionally a highly skilled and time intensive manual task.
- Providing network energy savings by optimizing the DU placements.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present embodiments, and the attendant advantages and features thereof, will be more readily understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

FIG. 1 shows an O-RAN concept with RU, the DU and CU;

FIG. 2 is a schematic diagram of an exemplary network architecture illustrating a communication system connected via an intermediate network to a host computer according to the principles in the present disclosure;

FIG. 3 is a block diagram of a host computer communicating via a network node with a wireless device over an at least partially wireless connection according to some embodiments of the present disclosure;

FIG. 4 is a flowchart illustrating exemplary methods implemented in a communication system including a host computer, a network node and a wireless device for executing a client application at a wireless device according to some embodiments of the present disclosure;

FIG. 5 is a flowchart illustrating exemplary methods implemented in a communication system including a host computer, a network node and a wireless device for receiving user data at a wireless device according to some embodiments of the present disclosure;

FIG. 6 is a flowchart illustrating exemplary methods implemented in a communication system including a host computer, a network node and a wireless device for receiving user data from the wireless device at a host computer according to some embodiments of the present disclosure;

FIG. 7 is a flowchart illustrating exemplary methods implemented in a communication system including a host computer, a network node and a wireless device for receiving user data at a host computer according to some embodiments of the present disclosure;

FIG. 8 is a flowchart of an exemplary process in a network node according to some embodiments of the present disclosure;

FIG. 9 shows an example 5G network with CA including CU, multiple DUs and RU serving multiple WDs according to some embodiments of the present disclosure.

DETAILED DESCRIPTION

Before describing in detail exemplary embodiments, it is noted that the embodiments reside primarily in combinations of apparatus components and processing steps related to network function placement with carrier aggregation in cloud network(s) using machine learning processes. Accordingly, components have been represented where appropriate by conventional symbols in the drawings, showing only those specific details that are pertinent to understanding the embodiments so as not to obscure the disclosure with details that will be readily apparent to those of ordinary skill in the art having the benefit of the description herein. Like numbers refer to like elements throughout the description.

As used herein, relational terms, such as “first” and “second,” “top” and “bottom,” and the like, may be used solely to distinguish one entity or element from another entity or element without necessarily requiring or implying any physical or logical relationship or order between such entities or elements. The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the concepts described herein. As used herein, the singular forms “a,” “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises,” “comprising,” “includes” and/or “including” when used herein, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

In embodiments described herein, the joining term, “in communication with” and the like, may be used to indicate electrical or data communication, which may be accomplished by physical contact, induction, electromagnetic radiation, radio signaling, infrared signaling or optical signaling, for example. One having ordinary skill in the art will appreciate that multiple components may interoperate and modifications and variations are possible of achieving the electrical and data communication.

In some embodiments described herein, the term “coupled,” “connected,” and the like, may be used herein to indicate a connection, although not necessarily directly, and may include wired and/or wireless connections.

The term “network node” used herein can be any kind of network node comprised in a radio network which may further comprise any of base station (BS), radio base station, base transceiver station (BTS), base station controller (BSC), radio

network controller (RNC), g Node B (gNB), evolved Node B (eNB or eNodeB), Node B, multi-standard radio (MSR) radio node such as MSR BS, multi-cell/multicast coordination entity (MCE), integrated access and backhaul (IAB) node, relay node, donor node controlling relay, radio access point (AP), transmission points, transmission nodes, Remote Radio Unit (RRU) Remote Radio Head (RRH), a core network node (e.g., mobile management entity (MME), self-organizing network (SON) node, a coordinating node, positioning node, MDT node, etc.), an external node (e.g., 3rd party node, a node external to the current network), nodes in distributed antenna system (DAS), a spectrum access system (SAS) node, an element management system (EMS),
 5 a node such as a cloud node (e.g., O-Cloud node), a CU, a DU, an RU, etc. The network node may also comprise test equipment. The term “radio node” used herein may be used to also denote a wireless device (WD) such as a wireless device (WD) or a radio network node.

In some embodiments, the non-limiting terms wireless device (WD) or a user
 15 equipment (UE) are used interchangeably. The WD herein can be any type of wireless device capable of communicating with a network node or another WD over radio signals, such as wireless device (WD). The WD may also be a radio communication device, target device, device to device (D2D) WD, machine type WD or WD capable of machine to machine communication (M2M), low-cost and/or low-complexity WD, a
 20 sensor equipped with WD, Tablet, mobile terminals, smart phone, laptop embedded equipped (LEE), laptop mounted equipment (LME), USB dongles, Customer Premises Equipment (CPE), an Internet of Things (IoT) device, or a Narrowband IoT (NB-IOT) device, etc.

Also, in some embodiments the generic term “radio network node” is used. It
 25 can be any kind of a radio network node which may comprise any of base station, radio base station, base transceiver station, base station controller, network controller, RNC, evolved Node B (eNB), Node B, gNB, Multi-cell/multicast Coordination Entity (MCE), IAB node, relay node, access point, radio access point, Remote Radio Unit (RRU) Remote Radio Head (RRH).

30 Note further, that functions described herein as being performed by a wireless device or a network node may be distributed over a plurality of wireless devices and/or network nodes. In other words, it is contemplated that the functions of the network node and wireless device described herein are not limited to performance by a single physical device and, in fact, can be distributed among several physical devices.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms used herein should be interpreted as having a meaning that is consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

Referring now to the drawing figures, in which like elements are referred to by like reference numerals, there is shown in FIG. 2 a schematic diagram of a communication system 10, according to an embodiment, such as an O-RAN-type cellular network, which comprises an access network 12, such as a radio access network, and a core network 14. The access network 12 comprises a plurality of network nodes 16a, 16b, 16c (referred to collectively as network nodes 16), such as wireless access points, each defining a corresponding coverage area 18a, 18b, 18c (referred to collectively as coverage areas 18). A coverage area 18 may refer to a cell established by a network node 16. Thus, a cell may form a coverage area 18. As such, cell 18 is used interchangeably herein with coverage area 18. Each network node 16a, 16b, 16c is connectable to the core network 14 over a wired or wireless connection 20. A first wireless device (WD) 22a located in coverage area 18a is configured to wirelessly connect to, or be paged by, the corresponding network node 16a. A second WD 22b in coverage area 18b is wirelessly connectable to the corresponding network node 16b. While a plurality of WDs 22a, 22b (collectively referred to as wireless devices 22) are illustrated in this example, the disclosed embodiments are equally applicable to a situation where a sole WD is in the coverage area or where a sole WD is connecting to the corresponding network node 16. Note that although only two WDs 22 and three network nodes 16 are shown for convenience, the communication system may include many more WDs 22 and network nodes 16.

Although communication system 10 has been referred to as an O-RAN-type cellular network, the present disclosure is not limited as such and may include any cellular network such as a Third Generation Partnership Project (3GPP) cellular network. The 3GPP has developed and is developing standards for Fourth Generation (4G) (also referred to as Long Term Evolution (LTE)) and Fifth Generation (5G) (also referred to as New Radio (NR)) wireless communication systems. The 3GPP is also developing standards for Sixth Generation (6G) wireless communication networks. That is, the communication system 10 may be a 3GPP-type cellular network that may

support standards such as LTE and/or NR (5G) and/or 6G. Other wireless systems, including without limitation Wide Band Code Division Multiple Access (WCDMA), Worldwide Interoperability for Microwave Access (WiMax), Ultra Mobile Broadband (UMB) and Global System for Mobile Communications (GSM), may also benefit from exploiting the ideas covered within this disclosure.

Also, it is contemplated that a WD 22 can be in simultaneous communication and/or configured to separately communicate with more than one network node 16 and more than one type of network node 16. For example, a WD 22 can have dual connectivity with a network node 16 that supports LTE and the same or a different network node 16 that supports NR. As an example, WD 22 can be in communication with an eNB for LTE/E-UTRAN and a gNB for NR/NG-RAN.

The communication system 10 may itself be connected to a host computer 24, which may be embodied in the hardware and/or software of a standalone server, a cloud-implemented server, a distributed server or as processing resources in a server farm. The host computer 24 may be under the ownership or control of a service provider, or may be operated by the service provider or on behalf of the service provider. The connections 26, 28 between the communication system 10 and the host computer 24 may extend directly from the core network 14 to the host computer 24 or may extend via an optional intermediate network 30. The intermediate network 30 may be one of, or a combination of more than one of, a public, private or hosted network. The intermediate network 30, if any, may be a backbone network or the Internet. In some embodiments, the intermediate network 30 may comprise two or more sub-networks (not shown). Any one of access network 12, core network 14, and intermediate network 30 may be at least in part a cloud network.

The communication system of FIG. 2 as a whole enables connectivity between one of the connected WDs 22a, 22b and the host computer 24. The connectivity may be described as an over-the-top (OTT) connection. The host computer 24 and the connected WDs 22a, 22b are configured to communicate data and/or signaling via the OTT connection, using the access network 12, the core network 14, any intermediate network 30 and possible further infrastructure (not shown) as intermediaries. The OTT connection may be transparent in the sense that at least some of the participating communication devices through which the OTT connection passes are unaware of routing of uplink and downlink communications. For example, a network node 16 may not or need not be informed about the past routing of an incoming downlink

communication with data originating from a host computer 24 to be forwarded (e.g., handed over) to a connected WD 22a. Similarly, the network node 16 need not be aware of the future routing of an outgoing uplink communication originating from the WD 22a towards the host computer 24.

5 A network node 16 is configured to include a NN management unit 32 which is configured to perform any step and/or task and/or process and/or method and/or feature described in the present disclosure, e.g., NN functions. A wireless device 22 is configured to include a WD management unit 34 which is configured to perform any step and/or task and/or process and/or method and/or feature described in the present
10 disclosure, e.g., WD functions.

 Example implementations, in accordance with an embodiment, of the WD 22, network node 16 and host computer 24 discussed in the preceding paragraphs will now be described with reference to FIG. 2. In a communication system 10, a host computer 24 comprises hardware (HW) 38 including a communication interface 40 configured to
15 set up and maintain a wired or wireless connection with an interface of a different communication device of the communication system 10. The host computer 24 further comprises processing circuitry 42, which may have storage and/or processing capabilities. The processing circuitry 42 may include a processor 44 and memory 46. In particular, in addition to or instead of a processor, such as a central processing unit,
20 and memory, the processing circuitry 42 may comprise integrated circuitry for processing and/or control, e.g., one or more processors and/or processor cores and/or FPGAs (Field Programmable Gate Array) and/or ASICs (Application Specific Integrated Circuitry) adapted to execute instructions. The processor 44 may be configured to access (e.g., write to and/or read from) memory 46, which may comprise
25 any kind of volatile and/or nonvolatile memory, e.g., cache and/or buffer memory and/or RAM (Random Access Memory) and/or ROM (Read-Only Memory) and/or optical memory and/or EPROM (Erasable Programmable Read-Only Memory).

 Processing circuitry 42 may be configured to control any of the methods and/or processes described herein and/or to cause such methods, and/or processes to be
30 performed, e.g., by host computer 24. Processor 44 corresponds to one or more processors 44 for performing host computer 24 functions described herein. The host computer 24 includes memory 46 that is configured to store data, programmatic software code and/or other information described herein. In some embodiments, the software 48 and/or the host application 50 may include instructions that, when executed

by the processor 44 and/or processing circuitry 42, causes the processor 44 and/or processing circuitry 42 to perform the processes described herein with respect to host computer 24. The instructions may be software associated with the host computer 24.

5 The software 48 may be executable by the processing circuitry 42. The software 48 includes a host application 50. The host application 50 may be operable to provide a service to a remote user, such as a WD 22 connecting via an OTT connection 52 terminating at the WD 22 and the host computer 24. In providing the service to the remote user, the host application 50 may provide user data which is transmitted using the OTT connection 52. The “user data” may be data and information described herein
10 as implementing the described functionality. In one embodiment, the host computer 24 may be configured for providing control and functionality to a service provider and may be operated by the service provider or on behalf of the service provider. The processing circuitry 42 of the host computer 24 may enable the host computer 24 to observe, monitor, control, transmit to and/or receive from the network node 16 and or
15 the wireless device 22. The processing circuitry 42 of the host computer 24 may include a host management unit 54 configured to enable the service provider to observe/monitor/ control/transmit to/receive from the network node 16 and/or the wireless device 22.

The communication system 10 further includes a network node 16 provided in a
20 communication system 10 and including hardware 58 enabling it to communicate with the host computer 24 and with the WD 22. The hardware 58 may include a communication interface 60 for setting up and maintaining a wired or wireless connection with an interface of a different communication device of the communication system 10, as well as a radio interface 62 for setting up and maintaining at least a
25 wireless connection 64 with a WD 22 located in a coverage area 18 served by the network node 16. The radio interface 62 may be formed as or may include, for example, one or more RF transmitters, one or more RF receivers, and/or one or more RF transceivers. The communication interface 60 may be configured to facilitate a connection 66 to the host computer 24. The connection 66 may be direct or it may pass
30 through a core network 14 of the communication system 10 and/or through one or more intermediate networks 30 outside the communication system 10.

In the embodiment shown, the hardware 58 of the network node 16 further includes processing circuitry 68. The processing circuitry 68 may include a processor 70 and a memory 72. In particular, in addition to or instead of a processor, such as a

central processing unit, and memory, the processing circuitry 68 may comprise integrated circuitry for processing and/or control, e.g., one or more processors and/or processor cores and/or FPGAs (Field Programmable Gate Array) and/or ASICs (Application Specific Integrated Circuitry) adapted to execute instructions. The processor 70 may be configured to access (e.g., write to and/or read from) the memory 72, which may comprise any kind of volatile and/or nonvolatile memory, e.g., cache and/or buffer memory and/or RAM (Random Access Memory) and/or ROM (Read-Only Memory) and/or optical memory and/or EPROM (Erasable Programmable Read-Only Memory).

Thus, the network node 16 further has software 74 stored internally in, for example, memory 72, or stored in external memory (e.g., database, storage array, network storage device, etc.) accessible by the network node 16 via an external connection. The software 74 may be executable by the processing circuitry 68. The processing circuitry 68 may be configured to control any of the methods and/or processes described herein and/or to cause such methods, and/or processes to be performed, e.g., by network node 16. Processor 70 corresponds to one or more processors 70 for performing network node 16 functions described herein. The memory 72 is configured to store data, programmatic software code and/or other information described herein. In some embodiments, the software 74 may include instructions that, when executed by the processor 70 and/or processing circuitry 68, causes the processor 70 and/or processing circuitry 68 to perform the processes described herein with respect to network node 16. For example, processing circuitry 68 of the network node 16 may include a NN management unit 32 which is configured to perform any step and/or task and/or process and/or method and/or feature described in the present disclosure, e.g., NN functions. Further, processing circuitry 68 of the network node 16 may include CU 100, DU 102, and/or RU 104. CU 100 may be configured to perform centralized unit functions, DU 102 may be configured to perform distributed unit functions including distributed unit network functions, and RU 104 may be configured to perform radio unit functions such as in an O-RAN and/or 3GPP network. DU 102 may refer to a DU network function (DU NF), e.g., where DU 102 is a DU NF, performs a network function (DU NF) and/or comprises a DU NF.

The communication system 10 further includes the WD 22 already referred to. The WD 22 may have hardware 80 that may include a radio interface 82 configured to set up and maintain a wireless connection 64 with a network node 16 serving a

coverage area 18 in which the WD 22 is currently located. The radio interface 82 may be formed as or may include, for example, one or more RF transmitters, one or more RF receivers, and/or one or more RF transceivers.

5 The hardware 80 of the WD 22 further includes processing circuitry 84. The processing circuitry 84 may include a processor 86 and memory 88. In particular, in addition to or instead of a processor, such as a central processing unit, and memory, the processing circuitry 84 may comprise integrated circuitry for processing and/or control, e.g., one or more processors and/or processor cores and/or FPGAs (Field
10 Programmable Gate Array) and/or ASICs (Application Specific Integrated Circuitry) adapted to execute instructions. The processor 86 may be configured to access (e.g., write to and/or read from) memory 88, which may comprise any kind of volatile and/or nonvolatile memory, e.g., cache and/or buffer memory and/or RAM (Random Access Memory) and/or ROM (Read-Only Memory) and/or optical memory and/or EPROM (Erasable Programmable Read-Only Memory).

15 Thus, the WD 22 may further comprise software 90, which is stored in, for example, memory 88 at the WD 22, or stored in external memory (e.g., database, storage array, network storage device, etc.) accessible by the WD 22. The software 90 may be executable by the processing circuitry 84. The software 90 may include a client application 92. The client application 92 may be operable to provide a service to a
20 human or non-human user via the WD 22, with the support of the host computer 24. In the host computer 24, an executing host application 50 may communicate with the executing client application 92 via the OTT connection 52 terminating at the WD 22 and the host computer 24. In providing the service to the user, the client application 92 may receive request data from the host application 50 and provide user data in response
25 to the request data. The OTT connection 52 may transfer both the request data and the user data. The client application 92 may interact with the user to generate the user data that it provides.

The processing circuitry 84 may be configured to control any of the methods and/or processes described herein and/or to cause such methods, and/or processes to be
30 performed, e.g., by WD 22. The processor 86 corresponds to one or more processors 86 for performing WD 22 functions described herein. The WD 22 includes memory 88 that is configured to store data, programmatic software code and/or other information described herein. In some embodiments, the software 90 and/or the client application 92 may include instructions that, when executed by the processor 86 and/or processing

circuitry 84, causes the processor 86 and/or processing circuitry 84 to perform the processes described herein with respect to WD 22. For example, the processing circuitry 84 of the wireless device 22 may include a WD management unit 34 which is configured to perform any step and/or task and/or process and/or method and/or feature described in the present disclosure, e.g., WD functions. In some embodiments, the inner workings of the network node 16, WD 22, and host computer 24 may be as shown in FIG. 3 and independently, the surrounding network topology may be that of FIG. 2.

In FIG. 3, the OTT connection 52 has been drawn abstractly to illustrate the communication between the host computer 24 and the wireless device 22 via the network node 16, without explicit reference to any intermediary devices and the precise routing of messages via these devices. Network infrastructure may determine the routing, which it may be configured to hide from the WD 22 or from the service provider operating the host computer 24, or both. While the OTT connection 52 is active, the network infrastructure may further take decisions by which it dynamically changes the routing (e.g., on the basis of load balancing consideration or reconfiguration of the network).

The wireless connection 64 between the WD 22 and the network node 16 is in accordance with the teachings of the embodiments described throughout this disclosure. One or more of the various embodiments improve the performance of OTT services provided to the WD 22 using the OTT connection 52, in which the wireless connection 64 may form the last segment. More precisely, the teachings of some of these embodiments may improve the data rate, latency, and/or power consumption and thereby provide benefits such as reduced user waiting time, relaxed restriction on file size, better responsiveness, extended battery lifetime, etc.

In some embodiments, a measurement procedure may be provided for the purpose of monitoring data rate, latency and other factors on which the one or more embodiments improve. There may further be an optional network functionality for reconfiguring the OTT connection 52 between the host computer 24 and WD 22, in response to variations in the measurement results. The measurement procedure and/or the network functionality for reconfiguring the OTT connection 52 may be implemented in the software 48 of the host computer 24 or in the software 90 of the WD 22, or both. In embodiments, sensors (not shown) may be deployed in or in association with communication devices through which the OTT connection 52 passes;

the sensors may participate in the measurement procedure by supplying values of the monitored quantities exemplified above, or supplying values of other physical quantities from which software 48, 90 may compute or estimate the monitored quantities. The reconfiguring of the OTT connection 52 may include message format, retransmission settings, preferred routing etc.; the reconfiguring need not affect the network node 16, and it may be unknown or imperceptible to the network node 16. Some such procedures and functionalities may be known and practiced in the art. In certain embodiments, measurements may involve proprietary WD signaling facilitating the host computer's 24 measurements of throughput, propagation times, latency and the like. In some embodiments, the measurements may be implemented in that the software 48, 90 causes messages to be transmitted, in particular empty or 'dummy' messages, using the OTT connection 52 while it monitors propagation times, errors, etc.

Thus, in some embodiments, the host computer 24 includes processing circuitry 42 configured to provide user data and a communication interface 40 that is configured to forward the user data to a cellular network for transmission to the WD 22. In some embodiments, the cellular network also includes the network node 16 with a radio interface 62. In some embodiments, the network node 16 is configured to, and/or the network node's 16 processing circuitry 68 is configured to perform the functions and/or methods described herein for preparing/initiating/maintaining/supporting/ending a transmission to the WD 22, and/or preparing/terminating/maintaining/supporting/ending in receipt of a transmission from the WD 22.

In some embodiments, the host computer 24 includes processing circuitry 42 and a communication interface 40 that is configured to a communication interface 40 configured to receive user data originating from a transmission from a WD 22 to a network node 16. In some embodiments, the WD 22 is configured to, and/or comprises a radio interface 82 and/or processing circuitry 84 configured to perform the functions and/or methods described herein for preparing/initiating/maintaining/supporting/ending a transmission to the network node 16, and/or preparing/terminating/maintaining/supporting/ending in receipt of a transmission from the network node 16.

Although FIGS. 2 and 3 show various "units" such as NN management unit 32, and WD management unit 34 as being within a respective processor, it is contemplated that these units may be implemented such that a portion of the unit is stored in a

corresponding memory within the processing circuitry. In other words, the units may be implemented in hardware or in a combination of hardware and software within the processing circuitry.

FIG. 4 is a flowchart illustrating an exemplary method implemented in a communication system, such as, for example, the communication system of FIGS. 2 and 3, in accordance with one embodiment. The communication system may include a host computer 24, a network node 16 and a WD 22, which may be those described with reference to FIG. 3. In a first step of the method, the host computer 24 provides user data (Block S100). In an optional substep of the first step, the host computer 24 provides the user data by executing a host application, such as, for example, the host application 50 (Block S102). In a second step, the host computer 24 initiates a transmission carrying the user data to the WD 22 (Block S104). In an optional third step, the network node 16 transmits to the WD 22 the user data which was carried in the transmission that the host computer 24 initiated, in accordance with the teachings of the embodiments described throughout this disclosure (Block S106). In an optional fourth step, the WD 22 executes a client application, such as, for example, the client application 92, associated with the host application 50 executed by the host computer 24 (Block S108).

FIG. 5 is a flowchart illustrating an exemplary method implemented in a communication system, such as, for example, the communication system of FIG. 2, in accordance with one embodiment. The communication system may include a host computer 24, a network node 16 and a WD 22, which may be those described with reference to FIGS. 2 and 3. In a first step of the method, the host computer 24 provides user data (Block S110). In an optional substep (not shown) the host computer 24 provides the user data by executing a host application, such as, for example, the host application 50. In a second step, the host computer 24 initiates a transmission carrying the user data to the WD 22 (Block S112). The transmission may pass via the network node 16, in accordance with the teachings of the embodiments described throughout this disclosure. In an optional third step, the WD 22 receives the user data carried in the transmission (Block S114).

FIG. 6 is a flowchart illustrating an exemplary method implemented in a communication system, such as, for example, the communication system of FIG. 2, in accordance with one embodiment. The communication system may include a host computer 24, a network node 16 and a WD 22, which may be those described with

reference to FIGS. 2 and 3. In an optional first step of the method, the WD 22 receives input data provided by the host computer 24 (Block S116). In an optional substep of the first step, the WD 22 executes the client application 92, which provides the user data in reaction to the received input data provided by the host computer 24 (Block S118).

5 Additionally or alternatively, in an optional second step, the WD 22 provides user data (Block S120). In an optional substep of the second step, the WD provides the user data by executing a client application, such as, for example, client application 92 (Block S122). In providing the user data, the executed client application 92 may further consider user input received from the user. Regardless of the specific manner in which
10 the user data was provided, the WD 22 may initiate, in an optional third substep, transmission of the user data to the host computer 24 (Block S124). In a fourth step of the method, the host computer 24 receives the user data transmitted from the WD 22, in accordance with the teachings of the embodiments described throughout this disclosure (Block S126).

15 FIG. 7 is a flowchart illustrating an exemplary method implemented in a communication system, such as, for example, the communication system of FIG. 2, in accordance with one embodiment. The communication system may include a host computer 24, a network node 16 and a WD 22, which may be those described with reference to FIGS. 2 and 3. In an optional first step of the method, in accordance with
20 the teachings of the embodiments described throughout this disclosure, the network node 16 receives user data from the WD 22 (Block S128). In an optional second step, the network node 16 initiates transmission of the received user data to the host computer 24 (Block S130). In a third step, the host computer 24 receives the user data carried in the transmission initiated by the network node 16 (Block S132).

25 FIG. 8 is a flowchart of an exemplary process in a network node 16. One or more blocks described herein may be performed by one or more elements of network node 16 such as by one or more of processing circuitry 68 (including the NN management unit 32), processor 70, radio interface 62 and/or communication interface 60. Network node 16 such as via processing circuitry 68 and/or processor 70 and/or
30 radio interface 62 and/or communication interface 60 is configured to determine (Block S134) a plurality of distributed units network functions (DU NFs) (i.e., DUs 102) to be hosted by a group of NNs 16 of the plurality of NN 16 based on a delay target of each wireless device (WD) 22 of a plurality of WDs 22, where each DU NF is associated with at least a component carrier usable by at least one WD 22, the plurality of DU NFs

is determined using a learning process, and trigger (Block S136) each NN 16 of the group of NN 16 to host a corresponding DU NF of the plurality of DU NFs .

5 In some embodiments, the method further comprises performing modeling of the network and performing modeling of end-to-end delay in the network based on data collected in the network to determine the plurality of DU NFs.

In some other embodiments, determining the plurality of DUs 102 comprises determining a WD centric DU NF placement based on carrier aggregation parameters and performing a weighted sum of a delay and a number of NNs 16 used to host DU NFs for a plurality of component carriers.

10 In some embodiments, determining the plurality of DU NFs using the learning process comprises one or more of modeling a state as a delay satisfaction of users, determining an action, where the action is a placement of at least one DU NF for the at least component carrier in the network, and determining a reward. The reward is the weighted sum of the delay and the number of NNs used to host DU NFs for the
15 plurality of component carriers and the satisfaction of one or more constraints. The one or more constraints are based on computing capacity of the plurality of NNs, a bandwidth capacity of midhaul, inter-DU, and fronthaul links, and the delay target.

In some other embodiments, determining the plurality of DU NFs using the learning process comprises applying deep reinforcement learning-based DU placement
20 with carrier aggregation (DUPCA) to minimize a quantity of DU NFs that are to be hosted by the group of NNs 16 while satisfying the delay target of each WD 22.

Having described the general process flow of arrangements of the disclosure and having provided examples of hardware and software arrangements for implementing the processes and functions of the disclosure, the sections below provide
25 details and examples of arrangements for network function placement with carrier aggregation in cloud network(s) using machine learning processes.

FIG. 9 shows a 5G network with carrier aggregation (CA) including NNs 16 (e.g., NNs 16a-16k), WDs 22a, 22b, 22c, 22d, a CU 100, multiple DUs 102 (e.g., DU NFs) and RU 104 (e.g., in NN 16a) serving multiple WDs 22. A plurality of NNs 16 is
30 shown (e.g., an access network node 16a and multiple O-Cloud nodes). Using a CA technique, each WD 22 has a given set of supported component carriers (CCs). Each WD 22 has one primary cell 18 (PCell) and several activated secondary cells 18 (SCells). The PCell may be active at all times for a given WD 22. Network functions (NFs) of each DU related to each CC run in one NN 16 (e.g., O-Cloud node). The data

of each WD 22 is transmitted from the CU 100 to the serving DU 102 (e.g., DU NF) for the PCell of that WD 22. The PCell of each WD 22 has the role of distributing the user data among DUs of all activated CCs for that specific WD 22. Hence, there is an inter DU (IDU) communication between the DU 102 (e.g., DU NF) serving the PCell and the DU 102 (e.g., DU NF) serving the SCell of the given user (i.e., WD 22) in the given time interval.

For example, in the above scenario, there are six CCs and four WDs 22. As shown in FIG. 8, CC1 and CC3 are activated for WD 22a (UE1), while CC1, CC3 and CC4 are activated CCs for WD 22d (UE4). In this example, CC1 may be assumed to be the PCell for UE1 and UE4, and CC2 to be the PCell for UE2 and UE3. The data of each WD 22 must be received in its PCell and then it is split among all activated CCs.

In some embodiments, downlink traffic may be considered and the end-to-end delay from the CU 100 to each WD 22 determined. Decisions about NNs 16 (e.g., the O-Cloud nodes) which are to be selected to instantiate the NFs of the DUs 102 (e.g., DU NFs) for the CCs are executed every time duration (TD) and during TD, the decisions may not be changed. The arrived burst of data payloads of WD u (e.g., UE u) in the current duration time is transmitted from CU 100 to a NN 16 (e.g., a cloud node) serving the DU 102 (e.g., DU NF) of the WD PCell and then is split among its activated CCs.

The delay from CU to each WD 22 includes processing, transmission, propagation, and queuing. These delays are related to CU 100, DU nodes (NNs 16 hosting a DU 102, DU NFs, etc.) and RU 104; as well as MH, IDU and FH links. In some embodiments, to satisfy the delay target, the delay to transmit one data packet of each WD 22 must be lower than or equal to its target.

Noting the delay experienced by the WDs 22 (e.g., users), the delay may increase if the DU 102 (e.g., DU NF) of all CCs run in one NN 16. Moreover, if the DUs 102 (e.g., DU NFs) for the CCs are distributed in different nodes, the IDU delay, and the number of processing nodes increases. Thus, the delay may be minimized while minimizing the number of placed DUs and satisfying the delay target of each user. Optimization variables may include the optimum placement of DU 102 (e.g., DU NFs) for each CC. Further, a weighted sum scheme may be used to solve this multi-objective problem (the delay and the number of placed DUs). The problem, which may be non-linear, may be solved by using a Deep Reinforcement Learning (DRL) algorithm.

In some embodiments, using the DRL approach, a DU NF placement for each CC may be determined. In each iteration, the DU placement for the CCs, the wireless channel and the user traffic causes an environment change and accordingly the DRL agent gets a reward. An objective function determines the reward. In the DRL algorithm, the problem may be modeled as a Markov Decision Process (MDP). In the proposed MDP approach the following may be met:

- A state is modelled as the delay satisfaction of the users.
- The action is the placement of the DU 102 (e.g., DU NFs) for the CCs in the cloud network.
- The reward is the weighted sum of the delay and the number of consumed NNs 16 (e.g., cloud nodes) used for DUs and the satisfaction of one or more constraints. The constraints may depend on computing capacity of the NNs 16 (e.g., cloud nodes), the bandwidth capacity of the links (MH, IDU, FH) and the WD delay target.

By using an ML algorithm based on the DQN, i.e., a kind of DRL algorithm, an optimum solution for the stated delay problem may be determined. Specifically as part of the problem definition, the following formulation is defined:

$$O = \sum_{n \in \mathcal{N}} f\left(\sum_{m \in \mathcal{M}} x_m^n\right),$$

where $O(t)$ denotes the number of placed DUs 102 (e.g., DU NFs) at the current time, t , and

$$f(x) = \begin{cases} 1 & x > 0 \\ 0 & x = 0. \end{cases}$$

Constraints may ensure that the total computing resources in CU, RU and DU n are lower than a maximum resource. In addition, the constraints may ensure that the bandwidth requirements of the MH, IDU and FH links are supported.

One or more embodiments are applicable in cloud networks. In some embodiments, in order to gain the full optimization of DU NF placement, the DU NFs may be instantiated on any capable NN 16 (e.g., cloud node) and is not limited solely to NNs 16 that provide wireless communication to WDs 22 (and conversely is not excluded from to NNs 16 that provide wireless communication to WDs 22). As such, although FIG. 3 shows NN 16 in communication with WD 22, such illustration is for ease of explanation. Implementations are not limited solely to what is shown in FIG. 3 (or FIG. 2). The embodiments of the present disclosure are not limited to a type of network such as cloud networks and may be applicable to network, including those

conforming to O-RAN O-Cloud specifications, cloud networks supported by 3GPP, or those provided by cloud providers such as Microsoft Azure, Google, Apple, Amazon Web Services, etc.

As will be appreciated by one of skill in the art, the concepts described herein may be embodied as a method, data processing system, computer program product and/or computer storage media storing an executable computer program. Accordingly, the concepts described herein may take the form of an entirely hardware embodiment, an entirely software embodiment or an embodiment combining software and hardware aspects all generally referred to herein as a “circuit” or “module.” Any process, step, action and/or functionality described herein may be performed by, and/or associated to, a corresponding module, which may be implemented in software and/or firmware and/or hardware. Furthermore, the disclosure may take the form of a computer program product on a tangible computer usable storage medium having computer program code embodied in the medium that can be executed by a computer. Any suitable tangible computer readable medium may be utilized including hard disks, CD-ROMs, electronic storage devices, optical storage devices, or magnetic storage devices.

Some embodiments are described herein with reference to flowchart illustrations and/or block diagrams of methods, systems and computer program products. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer program instructions. These computer program instructions may be provided to a processor of a general purpose computer (to thereby create a special purpose computer), special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

These computer program instructions may also be stored in a computer readable memory or storage medium that can direct a computer or other programmable data processing apparatus to function in a particular manner, such that the instructions stored in the computer readable memory produce an article of manufacture including instruction means which implement the function/act specified in the flowchart and/or block diagram block or blocks.

The computer program instructions may also be loaded onto a computer or other programmable data processing apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer implemented process such that the instructions which execute on the computer or other programmable apparatus provide steps for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks.

It is to be understood that the functions/acts noted in the blocks may occur out of the order noted in the operational illustrations. For example, two blocks shown in succession may in fact be executed substantially concurrently or the blocks may sometimes be executed in the reverse order, depending upon the functionality/acts involved. Although some of the diagrams include arrows on communication paths to show a primary direction of communication, it is to be understood that communication may occur in the opposite direction to the depicted arrows.

Computer program code for carrying out operations of the concepts described herein may be written in an object oriented programming language such as Python, Java® or C++. However, the computer program code for carrying out operations of the disclosure may also be written in conventional procedural programming languages, such as the "C" programming language. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer. In the latter scenario, the remote computer may be connected to the user's computer through a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

Many different embodiments have been disclosed herein, in connection with the above description and the drawings. It will be understood that it would be unduly repetitious and obfuscating to literally describe and illustrate every combination and subcombination of these embodiments. Accordingly, all embodiments can be combined in any way and/or combination, and the present specification, including the drawings, shall be construed to constitute a complete written description of all combinations and subcombinations of the embodiments described herein, and of the manner and process of making and using them, and shall support claims to any such combination or subcombination.

Abbreviations that may be used in the preceding description include:

	CA	Carrier Aggregation
	CC	Component Carrier
	CNF	Containerized Network Function
5	CU	Central Unit
	DQN	Deep Q-Network
	DRL	Deep Reinforcement Learning
	DU	Distributed Unit
	DUPCA	DU Placement with Carrier Aggregation
10	FH	Front Haul
	IDU	Inter-DU
	MDP	Markov Decision Process
	MH	Mid Haul
	MILP	Mixed Integer Linear Problem
15	ML	Machine Learning
	NF	Network Function
	PCell	Primary Cell
	RAN	Radio Access Network
	RU	Radio Unit
20	Scell	Secondary Cell
	UE	User Equipment
	VNF	Virtualized Network Function

It will be appreciated by persons skilled in the art that the embodiments
 25 described herein are not limited to what has been particularly shown and described
 herein above. In addition, unless mention was made above to the contrary, it should be
 noted that all of the accompanying drawings are not to scale. A variety of
 modifications and variations are possible in light of the above teachings and following
 example embodiments.

Embodiments:

Embodiment A1. A first network node (NN) configured to communicate with a plurality of NNs in a network, the first network node configured to, and/or comprising a communication interface and/or comprising processing circuitry
 5 configured to:

determine a plurality of distributed unit (DU NFs) to be hosted by a group of NNs of the plurality of NNs based on a delay target of each wireless device (WD) of a plurality of WDs, each DU NF being associated with at least a component carrier usable by at least one WD, the plurality of DU NFs being determined using a learning
 10 process; and

trigger each NN of the group of NN to host a corresponding DU NF of the plurality of DU NFs.

Embodiment A2. The first network node of Embodiment A1, wherein the
 15 first NN is further configured to:

perform modeling of the network; and

perform modeling of end-to-end delay in the network based on data collected in the network to determine the plurality of DU NFs.

Embodiment A3. The first network node of any one of Embodiments A1 and A2, wherein determining the plurality of DUs comprises:

determining a WD centric DU NF placement based on carrier aggregation parameters; and

performing a weighted sum of a delay and a number of NNs used to host DU
 25 NFs for a plurality of component carriers.

Embodiment A4. The first network node of any one of Embodiments A1-A3, wherein determining the plurality of DU NFs using the learning process comprises one or more of:

30 modeling a state as a delay satisfaction of users;

determining an action, the action being a placement of at least one DU NF for the at least component carrier in the network; and

determining a reward, the reward being the weighted sum of the delay and the number of NNs used to host DU NFs for the plurality of component carriers and the

satisfaction of one or more constraints, the one or more constraints being based on computing capacity of the plurality of NNs, a bandwidth capacity of midhaul, inter-DU, and fronthaul links, and the delay target.

5 Embodiment A5. The first network node of any one of Embodiments A1-A4, wherein determining the plurality of DU NFs using the learning process comprises:
 applying deep reinforcement learning-based DU placement with carrier
 aggregation (DUPCA) to minimize a quantity of DUs that are to be hosted by the group
 of NNs while satisfying the delay target of each WD.

10

 Embodiment B1. A method implemented in a first network node (NN)
 configured to communicate with a plurality of NNs in a network, the method
 comprising:
 determining a plurality of distributed unit network functions (DU NFs) to be
 15 hosted by a group of NNs of the plurality of NN based on a delay target of each
 wireless device (WD) of a plurality of WDs, each DU NF being associated with at least
 a component carrier usable by at least one WD, the plurality of DU NFs being
 determined using a learning process; and
 triggering each NN of the group of NN to host a corresponding DU NF of the
 20 plurality of DU NFs.

 Embodiment B2. The method of Embodiment B1, wherein the method
 further comprises:
 performing modeling of the network; and
 25 performing modeling of end-to-end delay in the network based on data collected
 in the network to determine the plurality of DU NFs.

 Embodiment B3. The method of any one of Embodiments B1 and B2,
 wherein determining the plurality of DUs comprises:
 30 determining a WD centric DU NF placement based on carrier aggregation
 parameters; and
 performing a weighted sum of a delay and a number of NNs used to host DU
 NFs for a plurality of component carriers.

Embodiment B4. The method of any one of Embodiments B1-B3, wherein determining the plurality of DU NFs using the learning process comprises one or more of:

- modeling a state as a delay satisfaction of users;
- 5 determining an action, the action being a placement of at least one DU NF for the at least component carrier in the network; and
- determining a reward, the reward being the weighted sum of the delay and the number of NNs used to host DU NFs for the plurality of component carriers and the satisfaction of one or more constraints, the one or more constraints being based on
- 10 computing capacity of the plurality of NNs, a bandwidth capacity of midhaul, inter-DU, and fronthaul links, and the delay target.

Embodiment B5. The method of any one of Embodiments B1-B4, wherein determining the plurality of DU NFs using the learning process comprises:

- 15 applying deep reinforcement learning-based DU placement with carrier aggregation (DUPCA) to minimize a quantity of DUs that are to be hosted by the group of NNs while satisfying the delay target of each WD.

ABSTRACT

A method, system and apparatus are disclosed. A first network node (NN) configured to communicate with a with a plurality of NNs in a network is described. The first network node is configured to, and/or includes a communication interface
5 and/or processing circuitry configured to determine a plurality of distributed unit network functions (DU NFs) to be hosted by a group of NNs of the plurality of NNs based on a delay target of each wireless device (WD) of a plurality of WDs, where each DU NF is associated with at least a component carrier usable by at least one WD, and the plurality of DU NFs is determined using a learning process. Further, each NN of the
10 group of NN is triggered to host a corresponding DU NF of the plurality of DUs.

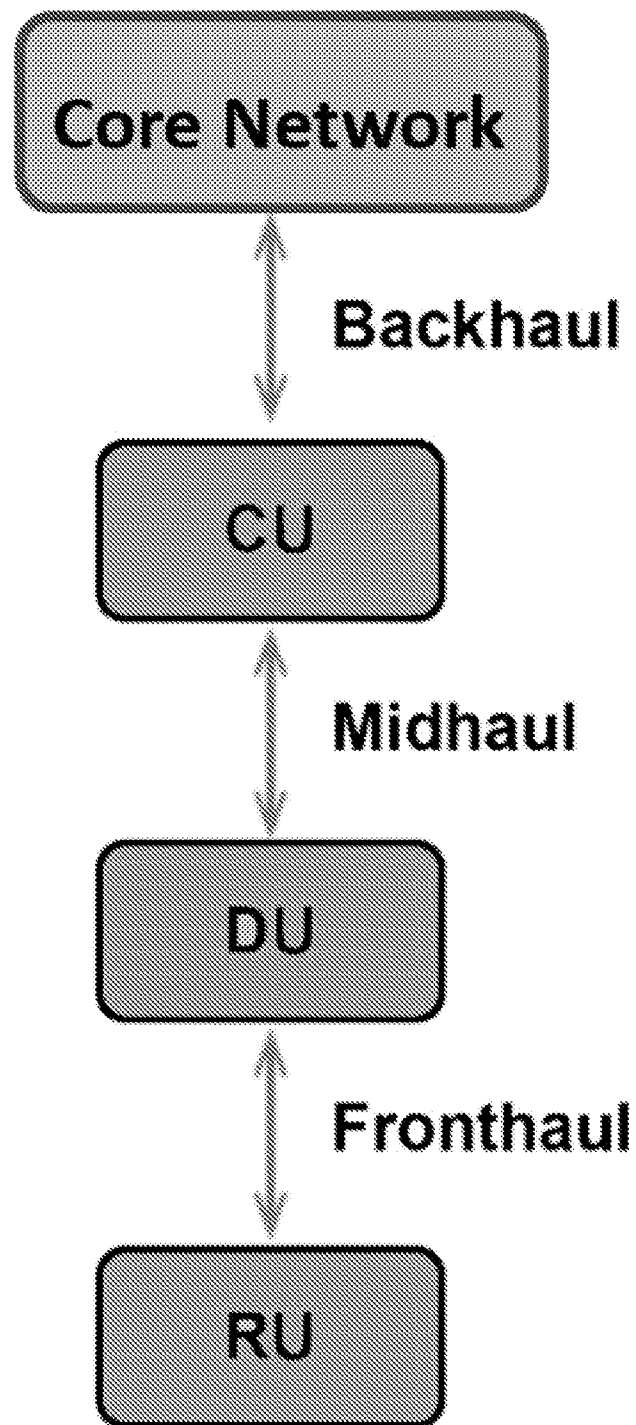


FIG. 1

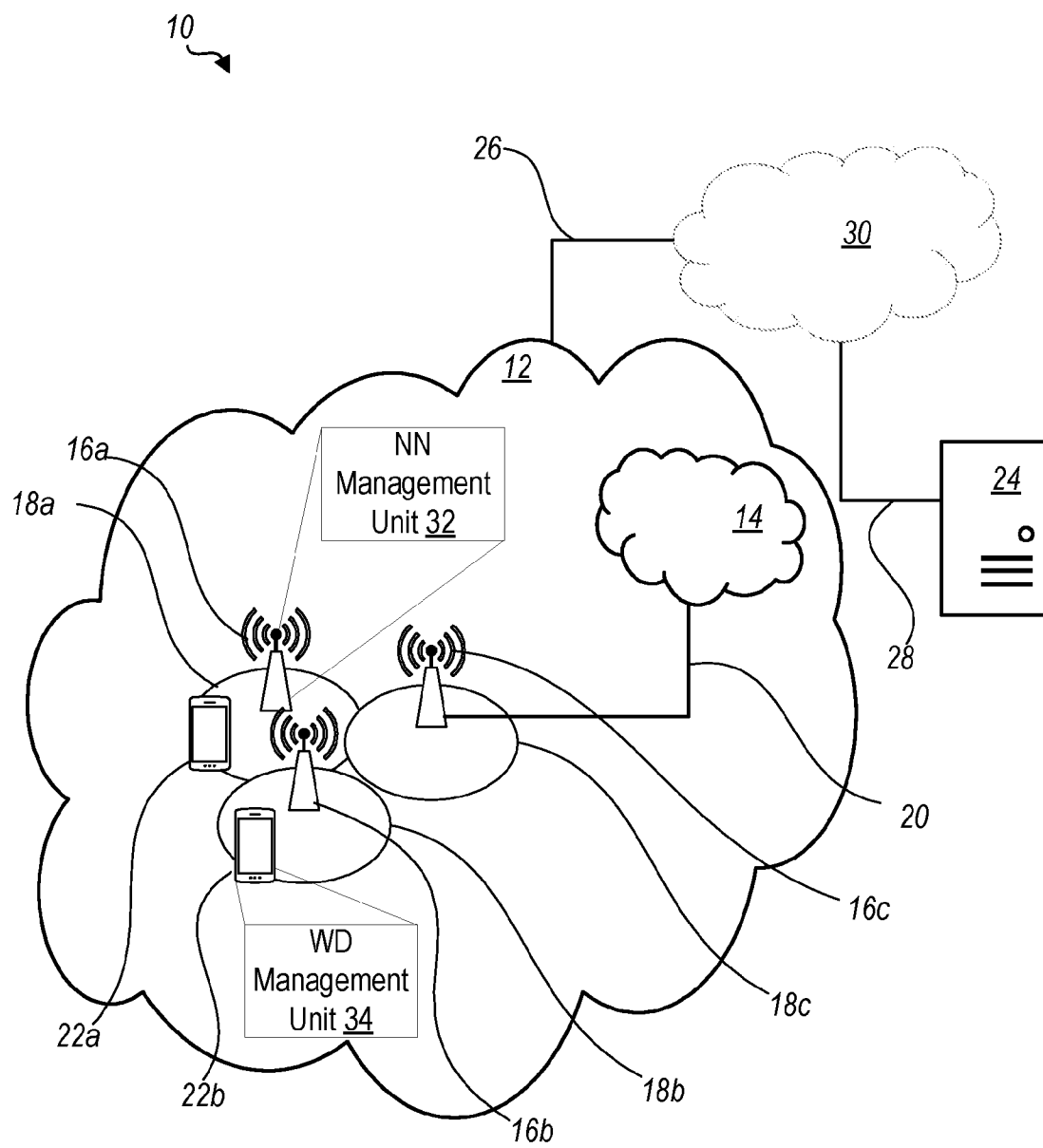


FIG. 2

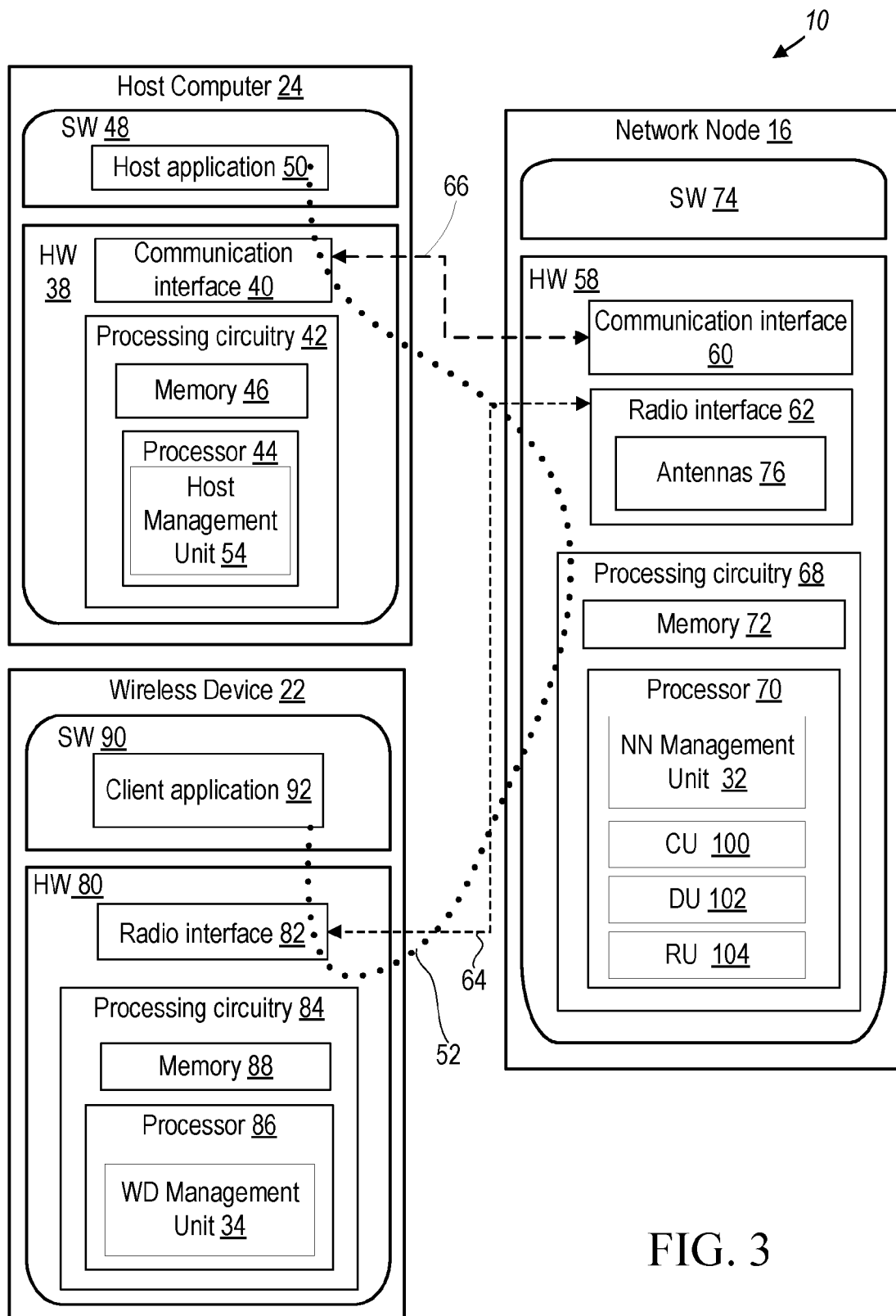


FIG. 3

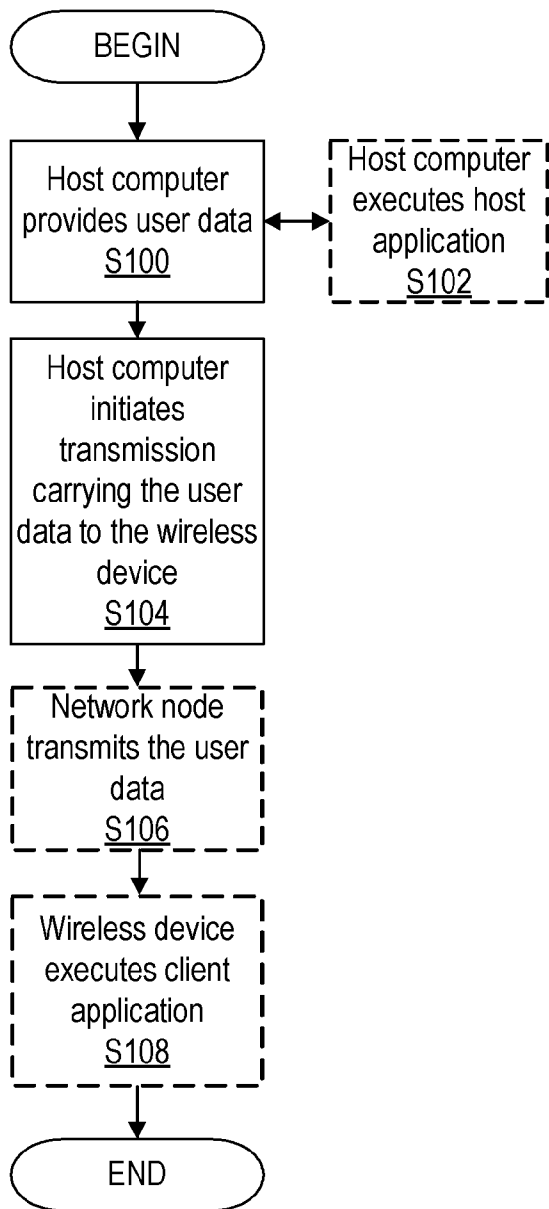


FIG. 4

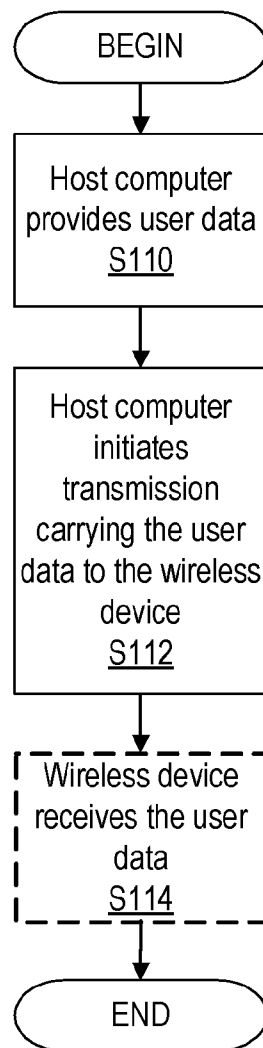


FIG. 5

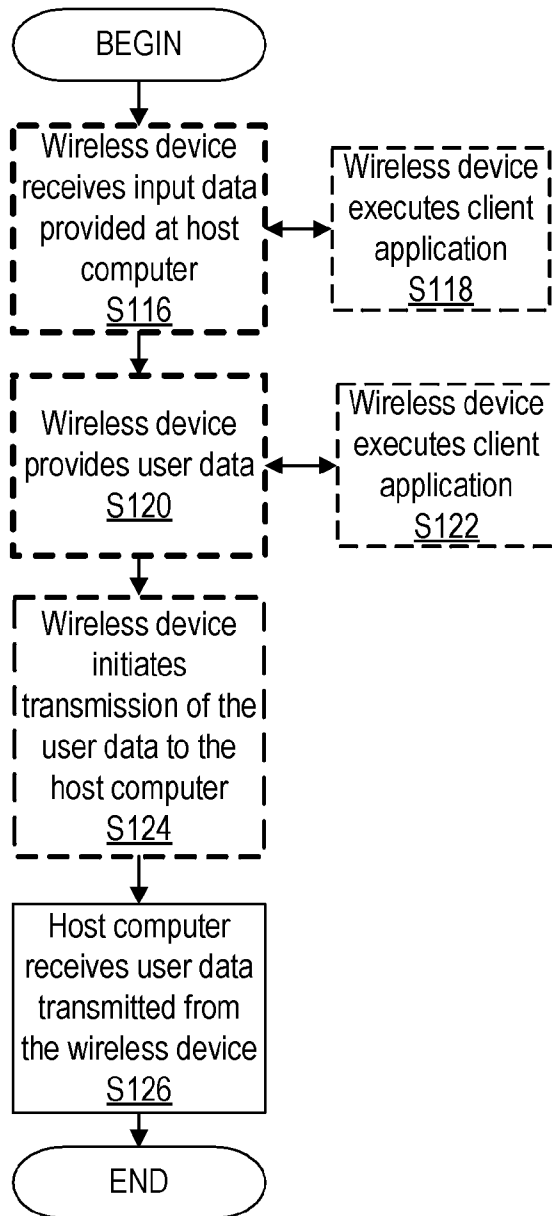


FIG. 6

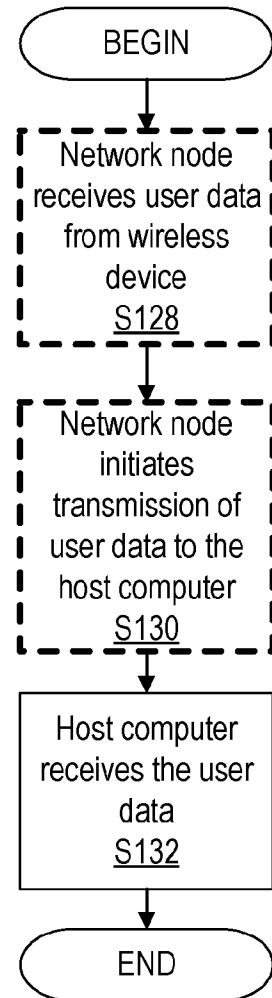


FIG. 7

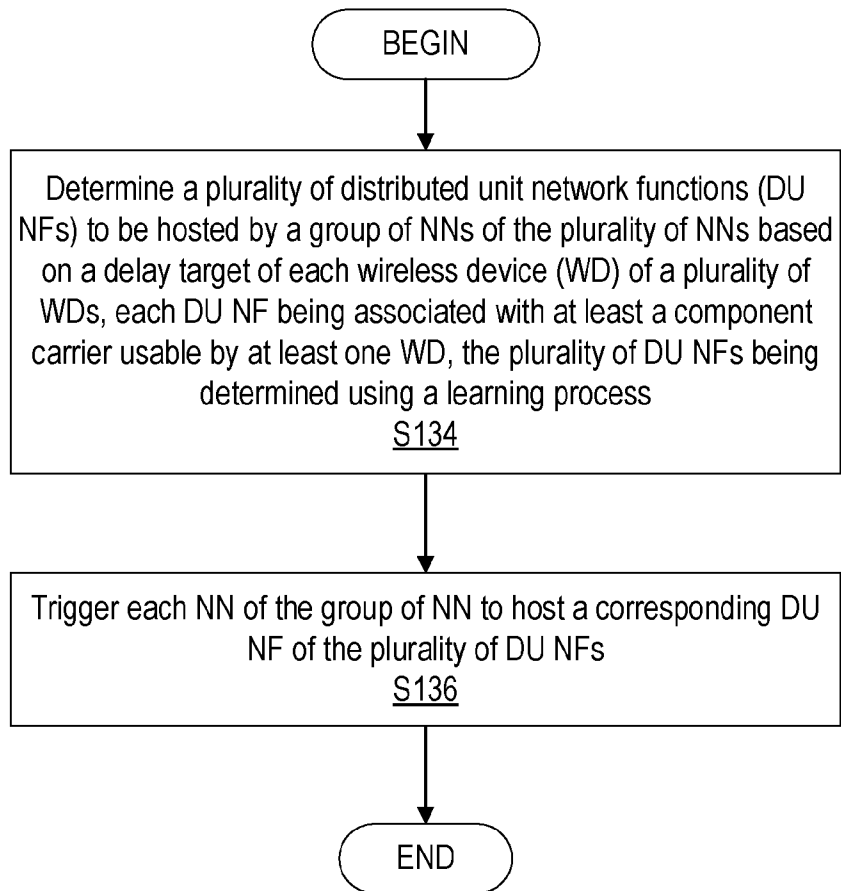


FIG. 8

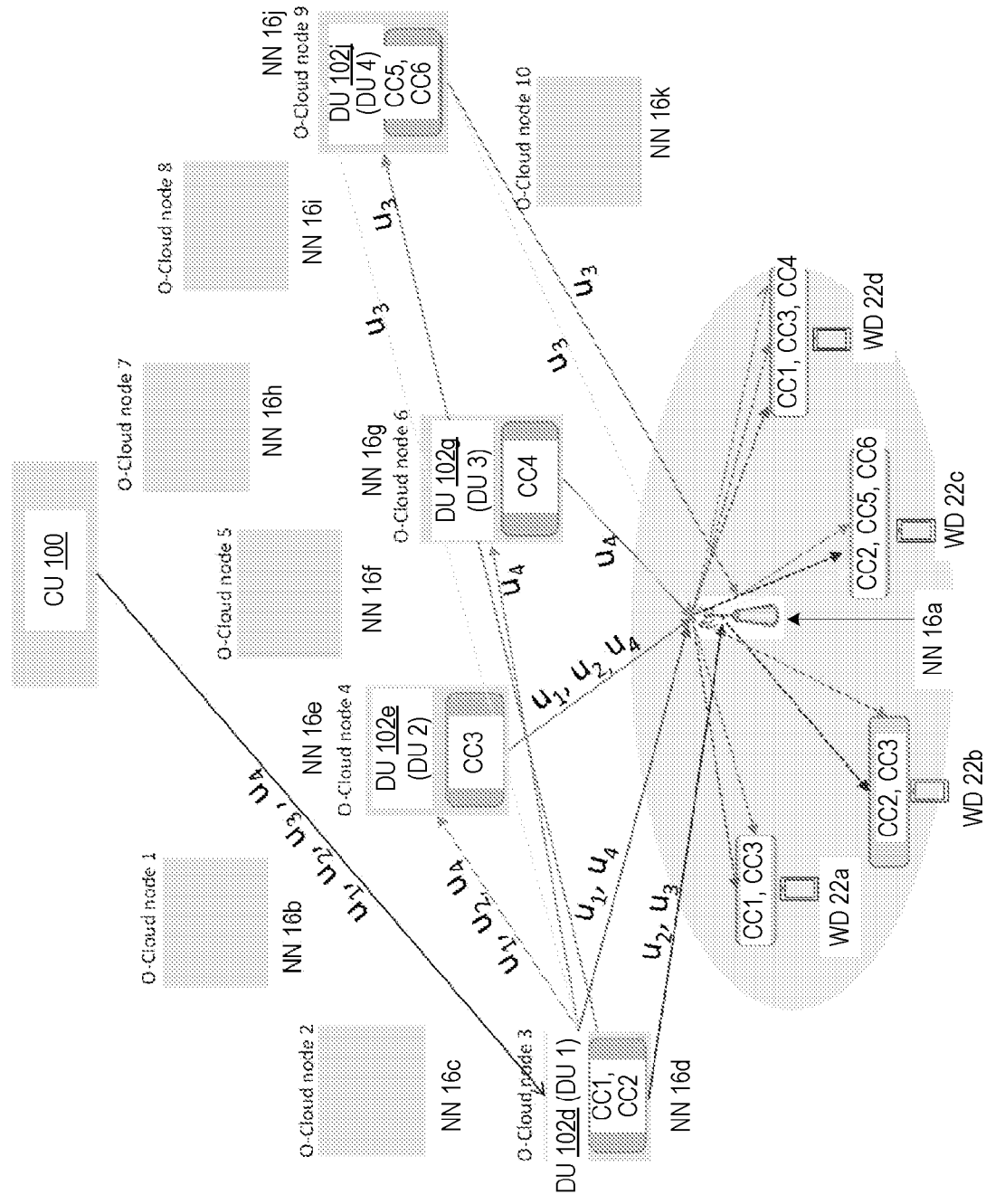


FIG. 9