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Kita

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(54) **ESTIMATION OF ROUTER THAT IS CAUSE OF SILENT FAILURES**

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H04L 43/08	(2022.01)
H04L 45/021	(2022.01)
H04W 24/02	(2009.01)
H04W 24/10	(2009.01)

(Continued)

(52) **U.S. Cl.**
CPC ***H04L 41/0631*** (2013.01); ***H04L 43/08*** (2013.01)

(58) **Field of Classification Search**
CPC ... H04L 41/0631; H04L 43/08; H04L 12/721; H04L 45/021; H04L 45/22; H04W 24/02; H04W 24/10; H04W 40/12; H04W 48/18
USPC 709/224
See application file for complete search history.

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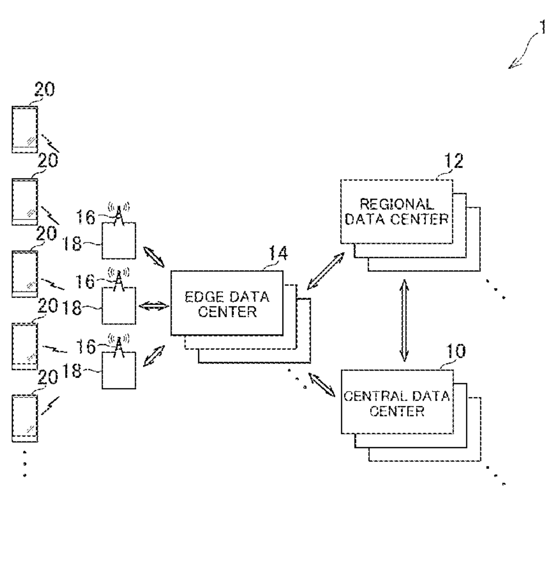
(57) **ABSTRACT**

Provided are a router estimation system and a router estimation method which enable accurate estimation of a router in network slices that is a cause of a silent failure. A policy manager (**90**) identifies, when a plurality of function elements are determined to have deteriorated in performance in slice communication, for each of the plurality of function elements determined to have deteriorated in performance, a group of routers located on a route of the slice communication, based on router group data. The policy manager (**90**) estimates at least one router included in every router group identified for the each of the plurality of function elements determined to have deteriorated in performance to be a router that is a cause of the deterioration of performance of the function element.

12 Claims, 10 Drawing Sheets



(51) **Int. Cl.**
H04W 40/12 (2009.01)
H04W 48/18 (2009.01)

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FIG.1

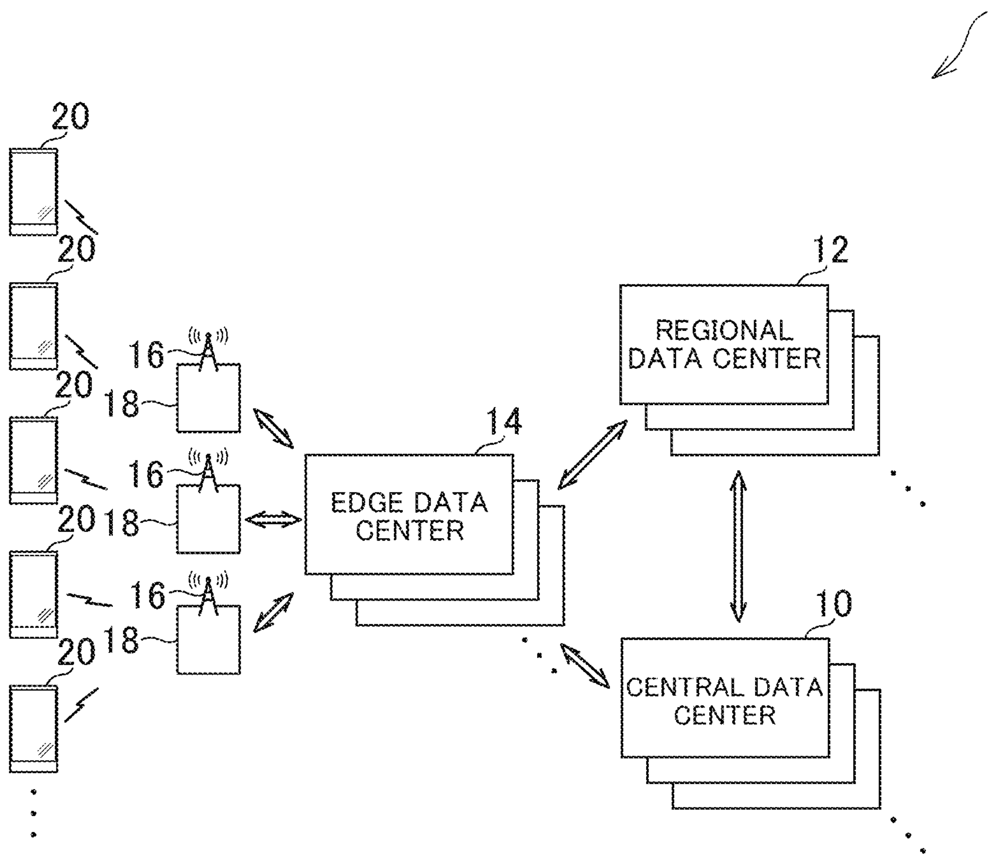

1
20
20
20
20
20
16
18
16
18
16
18
14
EDGE DATA CENTER
12
REGIONAL DATA CENTER
10
CENTRAL DATA CENTER

FIG.2

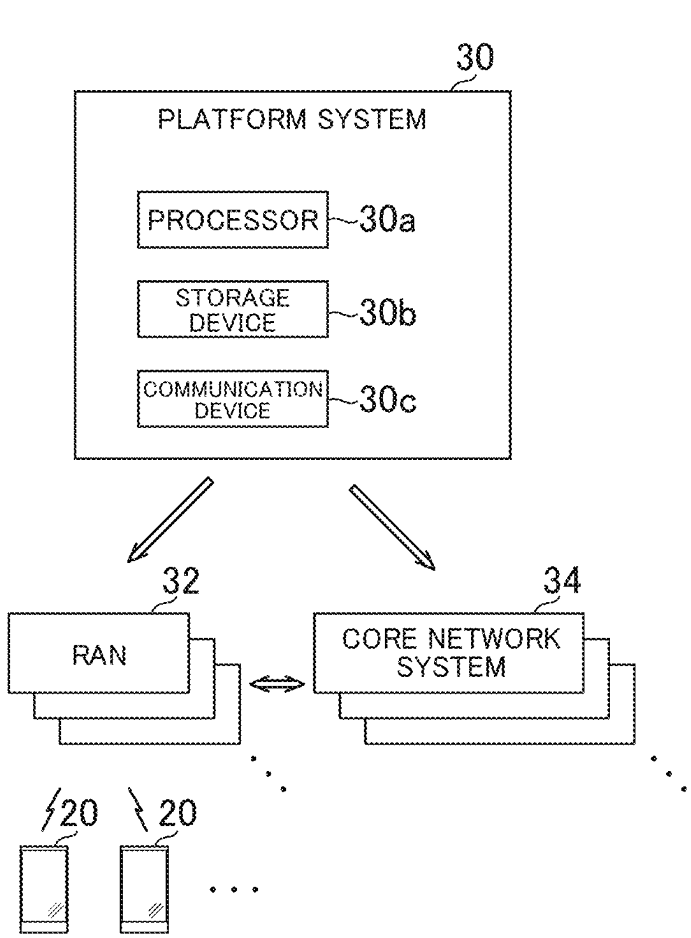

1
30
PLATFORM SYSTEM
PROCESSOR
30a
STORAGE DEVICE
30b
COMMUNICATION DEVICE
30c
32
RAN
34
CORE NETWORK SYSTEM
20
20

FIG.3

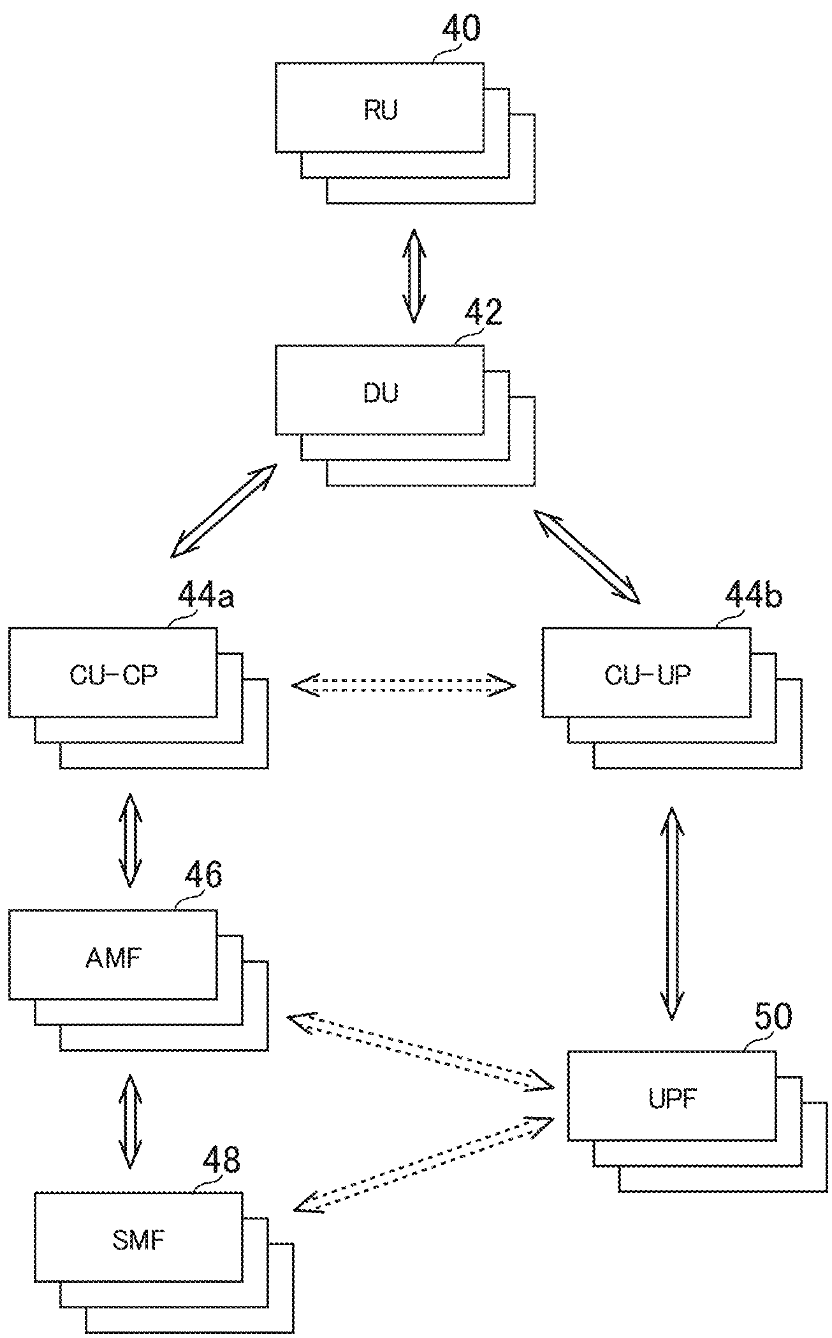


FIG.4

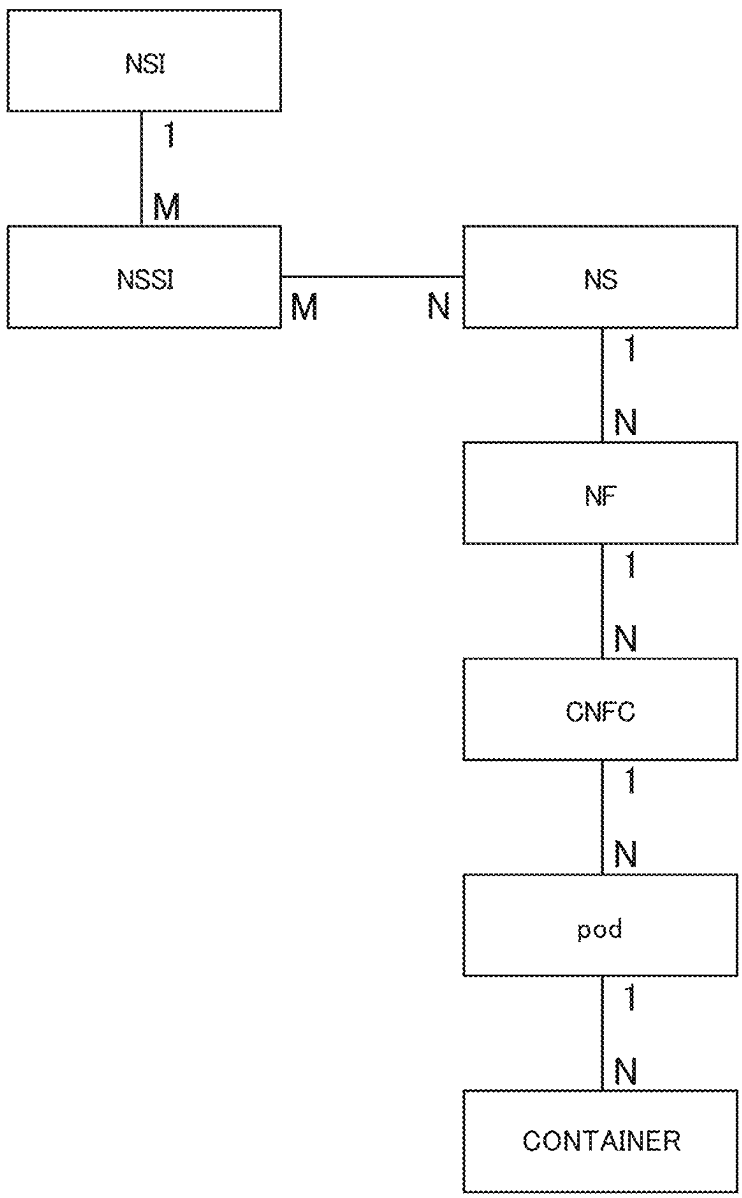


FIG.5

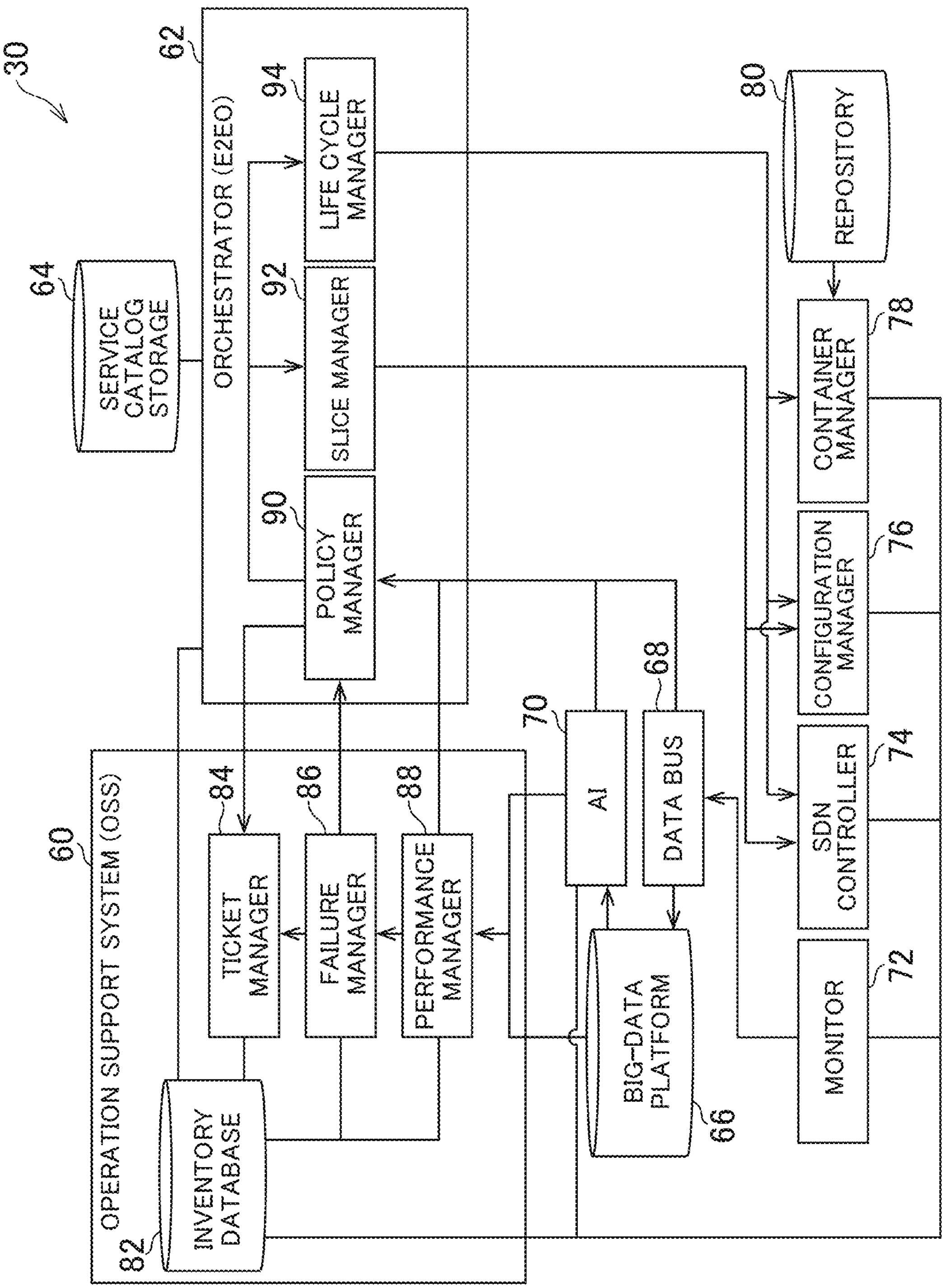

30
64
SERVICE CATALOG STORAGE
62
ORCHESTRATOR (E2EO)
90
POLICY MANAGER
92
SLICE MANAGER
94
LIFE CYCLE MANAGER
80
REPOSITORY
60
OPERATION SUPPORT SYSTEM (OSS)
82
INVENTORY DATABASE
84
TICKET MANAGER
86
FAILURE MANAGER
88
PERFORMANCE MANAGER
70
AI
68
DATA BUS
66
BIG-DATA PLATFORM
72
MONITOR
74
SDN CONTROLLER
76
CONFIGURATION MANAGER
78
CONTAINER MANAGER

FIG.6

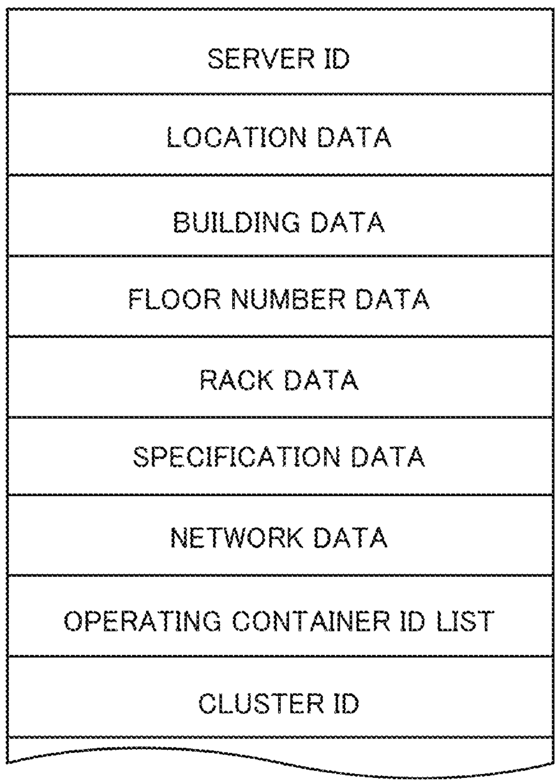

SERVER ID
LOCATION DATA
BUILDING DATA
FLOOR NUMBER DATA
RACK DATA
SPECIFICATION DATA
NETWORK DATA
OPERATING CONTAINER ID LIST
CLUSTER ID

FIG.7

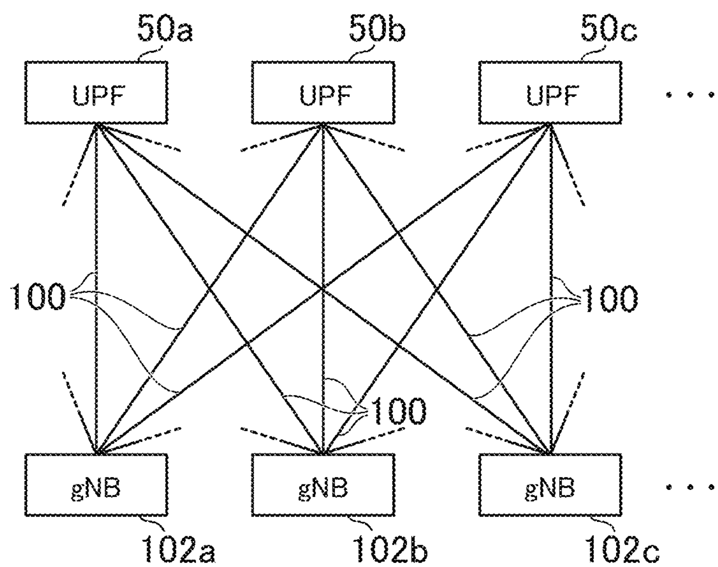


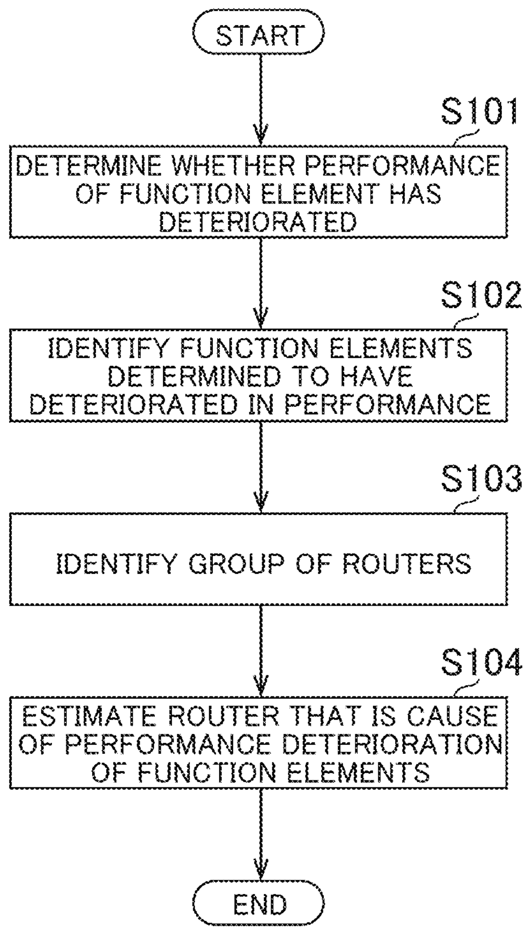
FIG.8

FUNCTION ELEMENT ID	SLICE ID	SEGMENT ROUTING PATH ID LIST
gNB001	001	001,002,003,・・・
gNB001	002	011,012,013,・・・
gNB001	003	021,022,023,・・・
gNB002	001	101,102,103,・・・
gNB002	002	111,112,113,・・・
gNB002	003	121,122,123,・・・
gNB003	001	201,202,203,・・・
gNB003	002	211,212,213,・・・
gNB003	003	221,222,223,・・・

FIG.9

SEGMENT ROUTING PATH ID	ROUTER ID LIST
011	10000,10001,10002,・・・,20001,・・・
012	10000,10011,10012,・・・
013	10000,10021,10022,・・・
101	11000,11001,11002,・・・
102	11000,11011,11012,・・・,20001,・・・
103	11000,11021,11022,・・・
221	12000,12001,12002,・・・
222	12000,12011,12012,・・・
223	12000,12021,12022,・・・,20001,・・・

FIG.10


START
S101
DETERMINE WHETHER PERFORMANCE OF FUNCTION ELEMENT HAS DETERIORATED
S102
IDENTIFY FUNCTION ELEMENTS DETERMINED TO HAVE DETERIORATED IN PERFORMANCE
S103
IDENTIFY GROUP OF ROUTERS
S104
ESTIMATE ROUTER THAT IS CAUSE OF PERFORMANCE DETERIORATION OF FUNCTION ELEMENTS
END

ESTIMATION OF ROUTER THAT IS CAUSE OF SILENT FAILURES

RELATED APPLICATIONS

The present application is a National Phase of International Application Number PCT/JP2023/010377, filed Mar. 16, 2023.

TECHNICAL FIELD

The present disclosure relates to estimation of a router that is a cause of silent failures.

BACKGROUND ART

In Patent Literature 1, there is described deployment of a plurality of network functions (NFs) included in a network service (NS) on a server in which a container-type application execution environment is installed. In Patent Literature 1, there are also described construction of network slices and monitoring of the NFs.

CITATION LIST

Patent Literature

[PTL 1] WO 2021/171210 A1

SUMMARY OF INVENTION

Technical Problem

In a communication system as described in Patent Literature 1, it is common to set a separate group of routers for each of the network slices as components. There is also a case in which a shared router is set as a component of a plurality of network slices.

Sometimes, despite detection of no trouble in a router that is a component shared by a plurality of network slices included in the communication system, a plurality of function elements (NSes, NFs, and the like) experience deterioration of performance (so-called silent failure) in communication that use network slices available to the function elements. A cause of such a silent failure is difficult to ascertain.

The present disclosure has been made in view of the circumstance described above, and an object of the present disclosure is to provide a router estimation system and a router estimation method which enable accurate estimation of a router in network slices that is a cause of a silent failure.

Solution to Problem

According to one embodiment of the present disclosure, there is provided a router estimation system including one or more processors, the router estimation system causing at least one of the one or more processors to execute a router group data storing process, a determination process, a router group identification process, and a router estimation process. In the router group data storing process, for each one of a plurality of network slices constructed in a communication system, router group data indicating a group of routers that form the each one of the plurality of network slices is stored. In the determination process, for each one of a plurality of function elements included in the communication system, and for each network slice available to the each one of the plurality of function elements, whether performance of the each one of the plurality of function elements in slice communication using the each network slice has deteriorated is determined. In the router group identification process, when a plurality of function elements out of the plurality of function elements included in the communication system are determined to have deteriorated in performance in the slice communication, for each of the plurality of function elements determined to have deteriorated in performance, a group of routers located on a route of the slice communication is identified based on the router group data. In the router estimation process, at least one router included in every router group identified for the each of the plurality of function elements determined to have deteriorated in performance is estimated to be a router that is a cause of the deterioration of performance of the plurality of function elements.

Further, according to one embodiment of the present disclosure, there is provided a router estimation method including storing, for each one of a plurality of network slices constructed in a communication system, router group data indicating a group of routers that form the each one of the plurality of network slices. The router estimation method also includes determining, for each one of a plurality of function elements included in the communication system, and for each network slice available to the each one of the plurality of function elements, whether performance of the each one of the plurality of function elements in slice communication using the each network slice has deteriorated. The router estimation method also includes identifying, when a plurality of function elements out of the plurality of function elements included in the communication system are determined to have deteriorated in performance in the slice communication, for each of the plurality of function elements determined to have deteriorated in performance, a group of routers located on a route of the slice communication, based on the router group data. The router estimation method also includes estimating at least one router included in every router group identified for the each of the plurality of function elements determined to have deteriorated in performance to be a router that is a cause of the deterioration of performance of the plurality of function elements.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a diagram for illustrating an example of a communication system in one embodiment of the present invention.

FIG. **2** is a diagram for illustrating an example of the communication system in the one embodiment of the present invention.

FIG. **3** is a diagram for schematically illustrating an example of a network service in the one embodiment of the present invention.

FIG. **4** is a diagram for illustrating an example of links between elements constructed in the communication system in the one embodiment of the present invention.

FIG. **5** is a functional block diagram for illustrating an example of functions implemented by a platform system in the one embodiment of the present invention.

FIG. **6** is a diagram for illustrating an example of data structure of physical inventory data.

FIG. **7** is a diagram for schematically illustrating an example of a configuration of a group of function elements which hold communication with use of network slices.

FIG. **8** is a table for showing an example of segment routing path management data.

FIG. **9** is a table for showing an example of router group management data.

FIG. **10** is a flow chart for illustrating an example of a flow of a process performed by the platform system in the one embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

One embodiment of the present invention is now described in detail with reference to the drawings.

FIG. **1** and FIG. **2** are each a diagram for illustrating an example of a communication system **1** in the one embodiment of the present invention. FIG. **1** is an illustration drawn with attention being given to locations of a data center group included in the communication system **1**. FIG. **2** is an illustration drawn with attention being given to various computer systems implemented in the data center group included in the communication system **1**.

As illustrated in FIG. **1**, the data center group included in the communication system **1** is classified into central data centers **10**, regional data centers **12**, and edge data centers **14**.

For example, several central centers **10** are dispersedly arranged in an area (for example, in Japan) covered by the communication system **1**.

For example, tens of regional data centers **12** are dispersedly arranged in the area covered by the communication system **1**. For example, when the area covered by the communication system **1** is the entire area of Japan, one or two regional data centers **12** may be arranged in each prefecture.

For example, thousands of edge data centers **14** are dispersedly arranged in the area covered by the communication system **1**. In addition, each of the edge data centers **14** can communicate to and from a communication facility **18** provided with an antenna **16**. Here, as illustrated in FIG. **1**, one edge data center **14** may be capable of communicating to and from several communication facilities **18**. The communication facility **18** may include a computer such as a server computer. The communication facility **18** in the present embodiment performs radio communication to and from a user equipment (UE) **20** via the antenna **16**. For example, a radio unit (RU) described later is arranged in the communication facility **18** provided with the antenna **16**.

A plurality of servers are arranged in each of the central data centers **10**, the regional data centers **12**, and the edge data centers **14** in the present embodiment.

In the present embodiment, for example, the central data centers **10**, the regional data centers **12**, and the edge data centers **14** can communicate to and from one another. Communication can also be performed between the central data centers **10**, between the regional data centers **12**, and between the edge data centers **14**.

As illustrated in FIG. **2**, the communication system **1** in the present embodiment includes a platform system **30**, a plurality of radio access networks (RANs) **32**, a plurality of core network systems **34**, and a plurality of UEs **20**. The core network systems **34**, the RANs **32**, and the UEs **20** cooperate with each other to implement a mobile communication network.

The RANs **32** are each a computer system which is provided with the antenna **16**, and corresponds to an eNodeB (eNB) in a fourth generation mobile communication system (hereinafter referred to as "4G") and an NR base station (gNB) in a fifth generation mobile communication system (hereinafter referred to as "5G"). The RANs **32** in the present embodiment are implemented mainly by server groups arranged in the edge data centers **14** and the communication facilities **18**. A part of the RANs **32** (for example, distributed unit (DU), central unit (CU), virtual distributed unit (vDU), or virtual central unit (vCU)) may be implemented by the central data center **10**, the regional data center **12**, or the communication facility **18** instead of the edge data center **14**.

The core network systems **34** are each a system corresponding to an evolved packet core (EPC) in 4G or a 5G core (5GC) in 5G. The core network systems **34** in the present embodiment are implemented mainly by server groups arranged in the central data centers **10** or the regional data centers **12**.

The platform system **30** in the present embodiment is configured, for example, on a cloud platform and includes a processor **30***a*, a storage device **30***b*, and a communication device **30***c*, as illustrated in FIG. **2**. The processor **30***a* is a program control device such as a microprocessor which operates in accordance with a program installed in the platform system **30**. The storage device **30***b* is, for example, a storage element such as a ROM or RAM, a solid state drive (SSD), a hard disk drive (HDD), or the like. The storage device **30***b* stores a program to be executed by the processor **30***a*, and the like. The communication device **30***c* is, for example, a communication interface, such as a network interface controller (NIC) or a wireless local area network (LAN) module. Software-defined networking (SDN) may be implemented in the communication device **30***c*. The communication device **30***c* exchanges data with the RAN **32** and the core network system **34**.

In the present embodiment, the platform system **30** is implemented by a server group arranged in the central data center **10**. The platform system **30** may be implemented by a server group arranged in the regional data center **12**.

In the present embodiment, for example, in response to a purchase request for a network service (NS) by a purchaser, the network service for which the purchase request has been made is constructed in the RAN **32** or the core network system **34**. Then, the constructed network service is provided to the purchaser.

For example, a network service such as a voice communication service, a data communication service, or the like, is provided to the purchaser who is a mobile virtual network operator (MVNO). The voice communication service or the data communication service provided in the present embodiment is eventually provided to a customer (end user) for the purchaser (MVNO in the above-mentioned example), who uses the UE **20** illustrated in FIG. **1** and FIG. **2**. The end user can perform voice communication or data communication to and from other users via the RAN **32** or the core network system **34**. The UE **20** of the end user can also access a data network such as the Internet via the RAN **32** or the core network system **34**.

In addition, in the present embodiment, an Internet of things (IoT) service may be provided to an end user who uses a robot arm, a connected car, or the like. In such a case, an end user who uses, for example, a robot arm, a connected car, or the like may be a purchaser of the network service in the present embodiment.

In the present embodiment, a container-type virtualized application execution environment such as Docker (trademark) is installed in the servers arranged in the central data center **10**, the regional data center **12**, and the edge data center **14**, and containers can be deployed in those servers and operated. In those servers, a cluster formed of one or more containers generated by such a virtualization technology may be constructed. For example, a Kubernetes cluster managed by a container management tool such as Kubernetes (trademark) may be constructed. Then, a processor on the constructed cluster may execute a container-type application.

The network service provided to the purchaser in the present embodiment is formed of one or a plurality of functional units (for example, network function (NF)). In the present embodiment, the functional unit is implemented by the NF implemented by the virtualization technology. The NE implemented by the virtualization technology is called "virtualized network function (VNF)." It does not matter what kind of virtualization technology has been used for virtualization. For example, a containerized network function (CNF) implemented by a container-type virtualization technology is also included in the VNF in the present description. The present embodiment is described on the assumption that the network service is implemented by one or a plurality of CNFs. The functional unit in the present embodiment may also correspond to a network node.

FIG. **3** is a diagram for schematically illustrating an example of an operating network service. The network service illustrated in FIG. **3** includes NFs, such as a plurality of RUs **40**, a plurality of DUs **42**, a plurality of CUs **44** (central unit-control planes (CU-CPs) **44***a* and central unit-user planes (CU-UPs) **44***b*), a plurality of access and mobility management functions (AMFs) **46**, a plurality of session management functions (SMFs) **48**, and a plurality of user plane functions (UPFs) **50**, as software elements.

In the example of FIG. **3**, the RU **40**, the DU **42**, the CU-CP **44***a*, the AMF **46**, and the SMF **48** correspond to elements of a control plane (C-Plane), and the RU **40**, the DU **42**, the CU-UP **44***b*, and the UPF **50** correspond to elements of a user plane (U-Plane).

The network service may include other types of NEs as software elements. In addition, the network service is implemented on a plurality of servers or other computer resources (hardware elements).

Then, in the present embodiment, for example, the network service illustrated in FIG. **3** provides a communication service in a certain area.

Then, in the present embodiment, it is assumed that the plurality of RUs **40**, the plurality of DUs **42**, the plurality of CU-UP **44***b*, and the plurality of UPFs **50**, which are illustrated in FIG. **3**, belong to one end-to-end network slice.

FIG. **4** is a diagram for schematically illustrating an example of links between elements constructed in the communication system **1** in the present embodiment. Symbols M and N indicated in FIG. **4** each represent any integer of 1 or more, and each indicate a relationship between the numbers of elements connected by a link. When the link has a combination of M and N at both ends thereof, the elements connected by the link have a many-to-many relationship. When the link has a combination of 1 and N or a combination of 1 and M at both ends thereof, the elements connected by the link have a one-to-many relationship.

As illustrated in FIG. **4**, a network service (NS), a network function (NF), a containerized network function component (CNFC), a pod, and a container have a hierarchical structure.

The NS corresponds to, for example, a network service formed of a plurality of NFs. Here, the NS may correspond to an element having a granularity, for example, a 5GC, an EPC, a 5G RAN (gNB), or a 4G RAN (eNB).

In 5G, the NF corresponds to an element having a granularity, for example, the RU, the DU, the CU-CP, the CU-UP, the AMF, the SMF, or the UPF. In 4G, the NF corresponds to an element having a granularity, for example, a mobility management entity (MME), a home subscriber server (HSS), a serving gateway (S-GW), a vDU, or a vCU. In the present embodiment, for example, one NS includes one or a plurality of NFs. That is, one or a plurality of NFs are under the control of one NS.

The CNFC corresponds to an element having a granularity, for example, DU mgmt or DU processing. The CNFC may be a microservice deployed on a server as one or more containers. For example, some CNFCs may be microservices that provide a part of the functions of the DU, the CU-CP, the CU-UP, and the like. Some CNFCs may be microservices that provide a part of the functions of the UPF, the AMF, the SMF, and the like. In the present embodiment, for example, one NF includes one or plurality of CNFCs. That is, one or a plurality of CNFCs are under the control of one NF.

The pod refers to, for example, the minimum unit for managing a Docker container by Kubernetes. In the present embodiment, for example, one CNFC includes one or a plurality of pods. That is, one or a plurality of pods are under the control of one CNFC.

In the present embodiment, for example, one pod includes one or a plurality of containers. That is, one or a plurality of containers are under the control of one pod.

In addition, as illustrated in FIG. **4**, a network slice (NSI) and a network slice subnet instance (NSSI) have a hierarchical structure.

The NSIs can be said to be end-to-end virtual circuits that span a plurality of domains (for example, from the RAN **32** to the core network system **34**). Each NSI may be a slice for high-speed and high-capacity communication (for example, for enhanced mobile broadband (eMBB)), a slice for high-reliability and low-latency communication (for example, for ultra-reliable and low latency communications (URLLC)), or a slice for connecting a large quantity of terminals (for example, for massive machine type communication (mMTC)). The NSSIs can be said to be single domain virtual circuits dividing an NSI. Each NSSI may be a slice of a RAN domain, a slice of a transport domain such as a mobile backhaul (MBH) domain, or a slice of a core network domain.

In the present embodiment, for example, one NSI includes one or a plurality of NSSIs. That is, one or a plurality of NSSIs are under the control of one NSI. In the present embodiment, a plurality of NSIs may share the same NSSI.

In addition, as illustrated in FIG. **4**, the NSSI and the NS generally have a many-to-many relationship.

In addition, in the present embodiment, for example, one NF can belong to one or a plurality of network slices. Specifically, for example, network slice selection assistance information (NSSAI) including one or a plurality of pieces of sub-network slice selection assist information (S-NSSAI) can be set for one NF. Here, the S-NSSAI is information associated with the network slice. The NF is not required to belong to the network slice.

FIG. **5** is a functional block diagram for illustrating an example of functions implemented by the platform system **30** in the present embodiment. The platform system **30** in the present embodiment is not required to implement all the functions illustrated in FIG. **5**, and may implement functions other than the functions illustrated in FIG. **5**.

As illustrated in FIG. **5**, the platform system **30** in the present embodiment functionally includes, for example, an operation support system (OSS) **60**, an orchestrator (end-to-end-orchestrator (E2EO)) **62**, a service catalog storage **64**, a big-data platform **66**, a data bus **68**, an artificial intelligence (AI) **70**, a monitor **72**, an SDN controller **74**, a configuration manager **76**, a container manager **78**, and a repository **80**. The OSS **60** includes an inventory database **82**, a ticket manager **84**, a failure manager **86**, and a performance manager **88**. The E2EO **62** includes a policy manager **90**, a slice manager **92**, and a life cycle manager **94**. Those elements are implemented mainly by the processor **30***a*, the storage device **30***b*, and the communication device **30***c*.

The functions illustrated in FIG. **5** may be implemented by executing, by the processor **30***a*, a program that is installed in the platform system **30**, which is one or a plurality of computers, and that includes instructions corresponding to the functions. The program may be supplied to the platform system **30** via a computer-readable information storage medium such as an optical disc, a magnetic disk, a magnetic tape, a magneto-optical disc, a flash memory, or the like, or via the Internet or the like. The functions illustrated in FIG. **5** may also be implemented by a circuit block, a memory, and other LSIs. Further, a person skilled in the art would understand that the functions illustrated in FIG. **5** can be implemented in various forms by only hardware, by only software, or by a combination of hardware and software.

The container manager **78** executes life cycle management of a container. For example, the life cycle management includes processes relating to the construction of the container such as the deployment and setting of the container.

Here, the platform system **30** in the present embodiment may include a plurality of container managers **78**. In each of the plurality of container managers **78**, a container management tool such as Kubernetes, and a package manager such as Helm may be installed. Each of the plurality of container managers **78** may execute the construction of a container such as the deployment of the container for a server group (for example, Kubernetes cluster) associated with the container manager **78**.

The container manager **78** is not required to be included in the platform system **30**. The container manager **78** may be provided in, for example, a server (that is, the RAN **32** or the core network system **34**) managed by the container manager **78**, or another server that is annexed to the server managed by the container manager **78**.

In the present embodiment, the repository **80** stores, for example, a container image of a container included in a functional unit group (for example, NF group) that achieves a network service.

The inventory database **82** is a database in which inventory information is stored. The inventory information includes, for example, information on a server arranged in the RAN **32** or the core network system **34** and managed by the platform system **30**.

In addition, in the present embodiment, the inventory database **82** stores inventory data. The inventory data indicates the current statuses of the configuration of an element group included in the communication system **1** and the link between the elements. In addition, the inventory data indicates the status of resources managed by the platform system **30** (for example, resource usage status). The inventory data may be physical inventory data or may be logical inventory data. The physical inventory data and the logical inventory data are described later.

FIG. **6** is a diagram for illustrating an example of data structure of the physical inventory data. The physical inventory data illustrated in FIG. **6** is associated with one server. The physical inventory data illustrated in FIG. **6** includes, for example, a server ID, location data, building data, floor number data, rack data, specification data, network data, operating container ID list, and a cluster ID.

The server ID included in the physical inventory data is, for example, an identifier of the server associated with the physical inventory data.

The location data included in the physical inventory data is, for example, data indicating the location of the server (for example, the address the location) associated with the physical inventory data.

The building data included in the physical inventory data is, for example, data indicating a building (for example, a building name) in which the server associated with the physical inventory data is arranged.

The floor number data included in the physical inventory data is, for example, data indicating a floor number at which the server associated with the physical inventory data is arranged.

The rack data included in the physical inventory data is, for example, an identifier of a rack in which the server associated with the physical inventory data is arranged.

The specification data included in the physical inventory data is, for example, data indicating the specifications of the server associated with the physical inventory data. The specification data indicates, for example, the number of cores, the memory capacity, and the hard disk capacity.

The network data included in the physical inventory data is, for example, data indicating information relating to a network of the server associated with the physical inventory data. The network data indicates, for example, an NIC included in the server, the number of ports included in the NIC, and a port ID of each of the ports.

The operating container ID list included in the physical inventory data is, for example, data indicating information relating to one or a plurality of containers operating in the server associated with the physical inventory data. The operating container ID list indicates, for example, a list of identifiers (container IDs) of instances of the containers.

The cluster ID included in the physical inventory data is, for example, an identifier of a cluster (for example, Kubernetes cluster) to which the server associated with the physical inventory data belongs.

The logical inventory data includes topology data for a plurality of elements included in the communication system **1**, which indicates the current status of such link between the elements as illustrated in FIG. **4**. For example, the logical inventory data includes topology data including an identifier of a certain NS and an identifier of one or a plurality of NFs under the control of the certain NS. In addition, for example, the logical inventory data includes topology data including an identifier of a certain network slice and an identifier of one or a plurality of NFs belonging to the certain network slice.

The inventory data may also include data indicated by the current status of, for example, a geographical relationship or a topological relationship between the elements included in the communication system **1**. As described above, the inventory data includes location data indicating locations at which the elements included in the communication system **1** are operating, that is, the current locations of the elements included in the communication system **1**. It can be said therefrom that the inventory data indicates the current status of the geographical relationship between the elements (for example, geographical closeness between the elements).

The logical inventory data may also include NSI data indicating information relating to a network slice. The NSI data indicates, for example, attributes such as an identifier of an instance of the network slice and the type of the network slice. The logical inventory data may also include NSSI data indicating information relating to a network slice subnet.

The NSSI data indicates, for example, attributes such as an identifier of an instance of the network slice subnet and the type of the network slice subnet.

The logical inventory data may also include NS data indicating information relating to an NS. The NS data indicates, for example, attributes such as an identifier of an instance of the NS and the type of the NS. The logical inventory data may also include NF data indicating information relating to an NF. The NF data indicates, for example, attributes such as an identifier of an instance of the NF and the type of the NF. The logical inventory data may also include CNFC data indicating information relating to the CNFC. The CNFC data indicates, for example, attributes such as an identifier of an instance and the type of the CNFC. The logical inventory data may also include pod data indicating information relating to the pod included in the CNFC. The pod data indicates, for example, attributes such as an identifier of an instance of the pod and the type of the pod. The logical inventory data may also include container data indicating information relating to the container included in the pod. The container data indicates, for example, attributes such as a container ID of an instance of the container and the type of the container.

With the container ID of the container data included in the logical inventory data and the container ID included in the operating container ID list included in the physical inventory data, an instance of the container and the server on which the instance of the container is operating become linked to each other.

Further, data indicating various attributes such as the host name and the IP address may be included in the above-mentioned data included in the logical inventory data. For example, the container data may include data indicating the IP address of a container corresponding to the container data. Further, for example, the NF data may include data indicating the IP address and the host name of an NF indicated by the NE data.

The logical inventory data may also include data indicating NSSAI including one or a plurality of pieces of S-NSSAI, which is set for each NF.

In addition, the inventory database **82** can appropriately grasp the resource status in cooperation with the container manager **78**. Then, the inventory database **82** appropriately updates the inventory data stored in the inventory database **82** based on the latest resource status.

Further, for example, the inventory database **82** updates the inventory data stored in the inventory database **82** in accordance with execution of an action, such as construction of a new element included in the communication system **1**, a change of a configuration of the elements included in the communication system **1**, scaling of the elements included in the communication included in the system **1**, or replacement of the elements communication system **1**.

The service catalog storage **64** stores service catalog data. The service catalog data may include, for example, service template data indicating the logic to be used by the life cycle manager **94** or the like. The service template data includes information required for constructing the network service. For example, the service template data includes information defining the NS, the NF, and the CNFC and information indicating an NS-NF-CNFC correspondence relationship. Further, for example, the service template data contains a workflow script for constructing the network service.

An NS descriptor (NSD) is an example of the service template data. The NSD is associated with a network service, and indicates, for example, the types of a plurality of functional units (for example, a plurality of CNFs) included in the network service. The NSD may indicate the number of CNFs or other functional units included in the network service for each type thereof. The NSD may also indicate a file name of a CNFD described later, which relates to the CNF included in the network service.

Further, a CNF descriptor (CNFD) is an example of the service template data. The CNFD may indicate computer resources (for example, CPU, memory, and hard disk drive) required by the CNF. For example, the CNFD may also indicate, for each of a plurality of containers included in the CNF, computer resources (CPU, memory, hard disk drive, and the like) required by the container.

The service catalog data may also include information to be used by the policy manager **90**, the information relating to a threshold value (for example, threshold value for abnormality detection) to be compared to the calculated performance index value. The performance index value is described later.

The service catalog data may also include, for example, slice template data. The slice template data includes information required for executing instantiation of the network slice, and includes, for example, the logic to be used by the slice manager **92**.

The slice template data includes information on a "generic network slice template" defined by the GSM Association (GSMA) ("GSM" is a trademark). Specifically, the slice template data includes network slice template data (NST), network slice subnet template data (NSST), and network service template data. The slice template data also includes information indicating the hierarchical structure of those elements which is illustrated in FIG. **4**.

In the present embodiment, for example, the life cycle manager **94** constructs a new network service for which a purchase request has been made in response to the purchase request for the NS by the purchaser.

The life cycle manager **94** may execute, for example, the workflow script associated with the network service to be purchased in response to the purchase request. Then, the life cycle manager **94** may execute the workflow script, to thereby instruct the container manager **78** to deploy the container included in the new network service to be purchased. Then, the container manager **78** may acquire the container image of the container from the repository **80** and deploy a container corresponding to the container image in the server.

In addition, in the present embodiment, the life cycle manager **94** executes, for example, scaling or replacement of the element included in the communication system **1**. Here, the life cycle manager **94** may output a container deployment instruction or deletion instruction to the container manager **78**. Then, the container manager **78** may execute, for example, a process of deploying a container or a process of deleting a container in accordance with the instruction. In the present embodiment, the life cycle manager **94** can execute such scaling and replacement that cannot be handled by Kubernetes of the container manager **78** or other tools.

The life cycle manager **94** may also output an instruction to create a communication route to the SDN controller **74**. For example, the life cycle manager **94** presents, to the SDN controller **74**, two IP addresses at both ends of a communication route to be created, and the SDN controller **74** creates a communication route connecting those two IP addresses to each other. The created communication route may be managed so as to be linked to those two IP addresses.

The life cycle manager **94** may also output, to the SDN controller **74**, an instruction to create a communication route between two IP addresses linked to the two IP addresses.

In the present embodiment, the slice manager **92** executes, for example, instantiation of a network slice. In the present embodiment, the slice manager **92** executes, for example, instantiation of a network slice by executing the logic indicated by the slice template stored in the service catalog storage **64**. The slice manager **92** includes, for example, a network slice management function (NSMF) and a network slice sub-network management function (NSSMF) described in the Third Generation Partnership Project (3GPP) (trademark) specification "TS28 533." The NSMF is a function of generating and managing network slices, and provides an NSI management service. The NSSMF is a function of generating and managing network slice subnets forming a part of a network slice, and provides an NSSI management service.

The slice manager **92** may output a configuration management instruction related to the instantiation of the network slice to the configuration manager **76**. Then, the configuration manager **76** may execute configuration management such as settings in accordance with the configuration management instruction.

The slice manager **92** may also present, to the SDN controller **74**, two IP addresses to output an instruction to create a communication route between those two IP addresses.

In the present embodiment, for example, the configuration manager **76** executes configuration management such as settings of the element group including the NFs in accordance with the configuration management instruction received from the life cycle manager **94** or the slice manager **92**.

In the present embodiment, for example, the SDN controller **74** creates the communication route between the two IP addresses linked to the creation instruction in accordance with the instruction to create the communication route, which has been received from the life cycle manager **94** or the slice manager **92**. The SDN controller **74** may create a communication route between two IP addresses through use of, for example, a publicly known path calculation method such as Flex Algo.

Here, for example, the SDN controller **74** may use a segment routing technology (for example, segment routing IPV6 (SRv6)) to construct an NSI and NSSI for the server or an aggregation router present between communication routes. In addition, the SDN controller **74** may generate an NSI and NSSI extending over a plurality of NFs to be set by issuing, to the plurality of NFs to be set, a command to set a common virtual local area network (VLAN) and a command to assign a bandwidth and a priority indicated by the setting information to the VLAN.

The SDN controller **74** may, for example, change the maximum value of the bandwidth that can be used for communication between two IP addresses without constructing a network slice.

The platform system **30** in the present embodiment may include a plurality of SDN controllers **74**. Each of the plurality of SDN controllers **74** may execute a process such as the creation of a communication route for a network device group including the aggregation routers associated with the SDN controller **74**.

In the present embodiment, the SDN controller **74** may appropriately change the created communication route. For example, the SDN controller **74** may detect occurrence of a failure in a network device associated with the SDN controller **74**, and in response to the detection, may switch the communication route that is created by the SDN controller **74** to run through the network device to a communication route that does not run through the network device.

The life cycle manager **94** or the slice manager **92** may output a change instruction to change a communication route to the SDN controller **74**. The SDN controller **74** may follow the change instruction to change a communication route created by the SDN controller **74**.

For example, the life cycle manager **94** or the slice manager **92** may output, to the SDN controller **74**, a change instruction to change a communication route linked to an identifier of a network device to be excluded from a communication route. When receiving the change instruction, the SDN controller **74** may switch a communication route created by the SDN controller **74** to a communication route from which the network device identified by the identifier linked to the change instruction is excluded (that is, a communication route that does not run through the network device identified by the identifier linked to the change instruction).

In the present embodiment, the monitor **72** monitors, for example, the element group included in the communication system **1** based on a given management policy. Here, for example, the monitor **72** may monitor the element group based on a monitoring policy designated by the purchaser when the purchaser purchases the network service.

In the present embodiment, the monitor **72** executes monitoring at various levels, for example, a slice level, an NS level, an NF level, a CNFC level, and a level of hardware such as the server.

For example, the monitor **72** may set a module that outputs metric data in the hardware such as the server or a software element included in the communication system **1** so that monitoring can be performed at the various levels described above. Here, for example, the NF may output the metric data indicating a metric that can be measured (that can be identified) by the NF to the monitor **72**. Further, the server may output the metric data indicating a metric relating to the hardware that can be measured (that can be identified) by the server to the monitor **72**.

In addition, for example, the monitor **72** may deploy, in the server, a sidecar container that aggregates the metric data indicating the metrics output from a plurality of containers in units of CNFCs (microservices). The sidecar container may include an agent called "exporter." The monitor **72** may repeatedly execute a process of acquiring the metric data aggregated in units of microservices from the sidecar container, at predetermined monitoring intervals through use of the mechanism of a monitoring tool such as Prometheus that can monitor a container management tool such as Kubernetes.

The monitor **72** may monitor performance index values regarding performance indices described in, for example, "TS 28.552, Management and orchestration; 5G performance measurements" or "TS 28.554, Management and orchestration; 5G end to end Key Performance Indicators (KPI)." Then, the monitor **72** may acquire metric data indicating the performance index values to be monitored.

Then, in the present embodiment, the monitor **72** executes, for example, a process (enrichment) of aggregating the metric data in predetermined aggregation units, to thereby generate performance index value data indicating the performance index values of the elements included in the communication system **1** in the aggregation units.

For example, for one gNB, the metric data indicating the metrics of the elements (for example, network nodes such as the DUs **42** and the CUs **44**) under the control of the gNB are aggregated, to thereby generate the performance index value data on the gNB. In such a manner, the performance index value data indicating communication performance in an area covered by the gNB is generated. Here, for example, the performance index value data indicating a plurality of types of communication performance, such as a traffic amount (throughput) and latency, may be generated for each gNB. In addition, the metric data indicating the metrics of a certain element (for example, DU **42**) during a predetermined period may be aggregated, to thereby generate the performance index value data indicating the communication performance of the element during the predetermined period. The communication performance indicated by the performance index value data is not limited to the traffic amount and the latency.

Then, the monitor **72** outputs, to the data bus **68**, the performance index value data generated by the above-mentioned enrichment.

In the present embodiment, the data bus **68** receives, for example, the performance index value data output from the monitor **72**. Then, the data bus **68** generates, based on one or a plurality of pieces of performance index value data that have been received, a performance index value file including the one or the plurality of pieces of performance index value data. Then, the data bus **68** outputs the generated performance index value file to the big-data platform **66**.

Further, the elements, such as the network slice, the NS, the NF, the CNFC, that are included in the communication system **1** and the hardware such as the server notify the monitor **72** of various alerts (for example, notify the monitor **72** of an alert with the occurrence of a failure as a trigger).

Then, for example, when the monitor **72** receives the above-mentioned notification of the alert, the monitor **72** outputs alert message data indicating the notification to the data bus **68**. Then, the data bus **68** generates an alert file obtained by combining one or a plurality of pieces of alert message data each indicating the notification into one file, and outputs the alert file to the big-data platform **66**.

In the present embodiment, the big-data platform **66** accumulates, for example, the performance index value files and the alert files that have been output from the data bus **68**.

In the present embodiment, for example, the AI **70** stores in advance a plurality of trained machine learning models. The AI **70** uses various machine learning models stored in the AI **70** to execute an estimation process such as a future prediction process for a use status and quality of service of the communication system **1**. The AI **70** may generate estimation result data indicating results of the estimation process.

The AI **70** may execute the estimation process based on the files accumulated in the big-data platform **66** and the above-mentioned machine learning models. The estimation process is suitable when long-term trend prediction is performed infrequently.

The AI **70** can also acquire the performance index value data stored in the data bus **68**. The AI **70** may execute the estimation process based on the performance index value data stored in the data bus **68** and the above-mentioned machine learning models. The estimation process is suitable when short-term prediction is performed frequently.

In the present embodiment, for example, the performance manager **88** calculates, based on a plurality of pieces of metric data, a performance index value (for example, KPI) that is based on metrics s indicated by those pieces of metric data. The performance manager **88** may calculate a performance index value (for example, performance index value relating to an end-to-end network slice) which is a comprehensive evaluation of a plurality of types of metrics and cannot be calculated from a single piece of metric data. The performance manager **88** may generate comprehensive performance index value data indicating a performance index value being a comprehensive evaluation.

The performance manager **88** may acquire the above-mentioned performance index value file from the big-data platform **66**. The performance manager **88** may also acquire the estimation result data from the AI **70**. Then, the performance index value such as the KPI may be calculated based on at least one of the performance index value file or the estimation result data. The performance manager **88** may acquire the metric data directly from the monitor **72**. Then, the performance index value such as the KPI may be calculated based on the metric data.

In the present embodiment, the failure manager **86** detects the occurrence of a failure in the communication system **1** based on, for example, at least any one of the above-mentioned metric data, the above-mentioned notification of the alert, the above-mentioned estimation result data, or the above-mentioned comprehensive performance index value data. The failure manager **86** may detect, for example, the occurrence of a failure that cannot be detected from a single piece of metric data or a single notification of the alert, based on a predetermined logic. The failure manager **86** may also generate detection failure data indicating the detected failure.

The failure manager **86** may acquire the metric data and the notification of the alert directly from the monitor **72**. The failure manager **86** may also acquire the performance index value file and the alert file from the big-data platform **66**. The failure manager **86** may also acquire the alert message data from the data bus **68**.

In the present embodiment, the policy manager **90** executes a predetermined determination process based on, for example, at least any one of the above-mentioned metric data, the above-mentioned performance index value data, the above-mentioned alert message data, the above-mentioned performance index value file, the above-mentioned alert file, the above-mentioned estimation result data, the above-mentioned comprehensive performance index value data, or the above-mentioned detection failure data.

Then, the policy manager **90** may execute an action corresponding to a result of the determination process. For example, the policy manager **90** may output an instruction to construct a network slice to the slice manager **92**. In addition, for example, the policy manager **90** may output, to the slice manager **92**, an instruction to switch the communication route. The policy manager **90** may also output an instruction for scaling or replacement of the elements to the life cycle manager **94** based on the result of the determination process.

The policy manager **90** in the present embodiment can acquire the performance index value data stored in the data bus **68**. Then, the policy manager **90** may execute the predetermined determination process based on the performance index value data acquired from the data bus **68**. The policy manager **90** may also execute the predetermined determination process based on the alert message data stored in the data bus **68**.

In the present embodiment, the ticket manager **84** generates, for example, a ticket indicating information to be notified to an administrator of the communication system **1**. The ticket manager **84** may generate a ticket indicating details of the detection failure data. The ticket manager **84** may also generate a ticket indicating a value of the performance index value data or the metric data. The ticket manager **84** may also generate a ticket indicating a determination result obtained by the policy manager **90**.

Then, the ticket manager **84** notifies the administrator of the communication system **1** of the generated ticket. The ticket manager **84** may transmit, for example, an email to which the generated ticket is attached to an email address of the administrator of the communication system **1**.

In the communication system **1** in the present embodiment, there may occur deterioration of the performance (so-called silent failure) of, for example, NSes and NFs, without an abnormality such as a failure being detected.

Now, an example of countermeasures to be taken against occurrence of a silent failure executed in the platform system **30** in the present embodiment is described. Elements in which a communication function is implemented, such as NSes and NFs, are hereinafter referred to as "function elements."

In the communication system **1** in the present embodiment, a plurality of network slices are constructed. A separate group of routers is set as components for each of the plurality of network slices constructed in the communication system **1** in the present embodiment. A router shared by the plurality of network slices may be set as a component.

FIG. **7** is a diagram for schematically illustrating an example of a configuration of a group of function elements each of which holds communication with use of a network slice that is one of the plurality of network slices constructed in the communication system **1** in the present embodiment.

The network slice illustrated in FIG. **7** includes a plurality of segment routing paths **100** as components. In the present embodiment, each of the plurality of network slices constructed in the communication system **1** may thus include one or a plurality of segment routing paths **100** as components. Packet forwarding by segment routing (for example, packet forwarding by SRv6 or by Segment Routing Multi-Protocol Label Switching (SRMPLS)) is executed on the segment routing paths **100**. Each of the plurality of segment routing paths **100** may include routers as components. A router shared by the plurality of segment routing paths **100** may be set as a component.

In the present embodiment, one or a plurality of network slices out of the plurality of network slices constructed in the communication system **1** are available to each one of the function elements included in the communication system **1**. The function element included in the communication system **1** can use the network slice available to the function element to hold communication. Communication held by the function element with the use of the network slice available to the function element is hereinafter referred to as "slice communication."

In the example of FIG. **7**, the group of function elements which hold communication with the use of the network slice includes a plurality of UPFs **50** (**50***a*, **50***b*, **50***c* . . .) and a plurality of gNBs **102** (**102***a*, **102***b*, **102***c* . . .). The gNBs **102** include the DUs **42** and the CUS **44**. The group of function elements which hold communication with the use of the network slice may include other types of function elements (for example, the AMFs **46** and SMFs **48**).

In the communication system **1** in the present embodiment, for each of the plurality of network slices constructed in the communication system **1**, a group of routers that form the network slice is managed. For example, the inventory database **82** may store, for each of the plurality of network slices constructed in the communication system **1**, router group data indicating the group of routers that form the network slice.

The router group data in the present embodiment may include, for example, segment routing path management data exemplified in FIG. **8** and router group management data exemplified in FIG. **9**.

The segment routing path management data in the present embodiment is, for example, data indicating one or a plurality of segment routing paths out of the segment routing paths **100** on which packets are forwarded in communication held by a function element with the use of a network slice available to the function element.

As shown in FIG. **8**, the segment routing path management data includes, for example, a function element ID, a slice ID, and a segment routing path ID list.

A piece of segment routing path management data links a function element ID which is an identifier of a function element to a slice ID which is an identifier of a network slice available to the function element. The piece of segment routing path management data also links a segment routing path ID list, which is a list of identifiers of the segment routing paths **100** (segment routing path IDs) on which packets are forwarded in communication held by the function element with the use of the network slice.

Identifiers of the gNB **102***a*, the gNB **102***b*, and the gNB **102***c* here are "gNB001," "gNB002," and "gNB003," respectively.

In such a case, the segment routing path management data shown in FIG. **8** indicates that a plurality of network slices including three network slices that have slice IDs "001," "002," and "003" are available to every one of the gNB **102***a*, the gNB **102***b*, and the gNB **102***c*. It is not required to set network slices so that available network slices are common to all function elements. Available network slices may vary from one function element to another function element.

The network slice that has the slice ID "001" is hereinafter referred to as "first network slice." The network slice that has the slice ID "002" is hereinafter referred to as "second network slice." The network slice that has the slice ID "003" is hereinafter referred to as "third network slice."

For example, when slice communication using the first network slice is held by the gNB **102***a*, the communication is held with use of one of the segment routing paths **100** that has one of "001," "002," "003" . . . as the segment routing path ID. When slice communication using the second network slice is held by the gNB **102***a*, the communication is held with the use of one of the segment routing paths **100** that has one of "011," "012," "013" . . . as the segment routing path ID. When slice communication using the third network slice is held by the gNB **102***a*, the communication is held with the use of one of the segment routing paths **100** that has one of "021," "022," "023" . . . as the segment routing path ID.

Further, when slice communication using the first network slice is held by the gNB **102***b*, the communication is held with use of one of the segment routing paths **100** that has one of "101," "102," "103" . . . as the segment routing path ID. When slice communication using the second network slice is held by the gNB **102***b*, the communication is held with the use of one of the segment routing paths **100** that has one of "111," "112," "113" . . . as the segment routing path ID. When slice communication using the third network slice is held by the gNB **102***b*, the communication is held with the use of one of the segment routing paths **100** that has one of "121," "122," "123" . . . as the segment routing path ID.

Further, when slice communication using the first network slice is held by the gNB **102***c*, the communication is held with use of one of the segment routing paths **100** that has one of “201,” “202,” “203” . . . as the segment routing path ID. When slice communication using the second network slice is held by the gNB **102***c*, the communication is held with the use of one of the segment routing paths **100** that has one of “211,” “212,” “213” . . . as the segment routing path ID. When slice communication using the third network slice is held by the gNB **102***c*, the communication is held with the use of one of the segment routing paths **100** that has one of “221,” “222,” “223” . . . as the segment routing path ID.

The router group management data in the present embodiment is, for example, data indicating, for each one of the plurality of segment routing paths **100**, a group of routers that are components of the segment routing path **100**.

As shown in FIG. **9**, the router group management data includes, for example, a segment routing path ID and a router ID list. The segment routing path ID is an identifier of one of the segment routing paths **100**. As described above, the segment routing path ID corresponds to an element of the segment routing path ID list included in the segment routing path management data. The router group management data links the segment routing path ID to a router ID list, which is a list of identifiers of routers (router IDs) that are components of the one of the segment routing paths **100** that is identified by the segment routing path ID.

For example, the router group management data shown in FIG. **9** indicates that a plurality of routers that form one of the segment routing paths **100** that has the segment routing path ID “011” have identifiers “10000,” “10001,” “10002” . . . “20001” . . . . The router group management data also indicates that a plurality of routers that form one of the segment routing paths **100** that has the segment routing path ID “012” have identifiers “10000,” “10011,” “10012” . . . . The router group management data also indicates that a plurality of routers that form one of the segment routing paths **100** that has the segment routing path ID “013” have identifiers “10000,” “10021,” “10022” . . . .

The router group management data also indicates that a plurality of routers that form one of the segment routing paths **100** that has the segment routing path ID “101” have identifiers “11000,” “11001,” “11002” . . . . The router group management data also indicates that a plurality of routers that form one of the segment routing paths **100** that has the segment routing path ID “102” have identifiers “11000,” “11011,” “11012”. “20001” . . . . The router group management data also indicates that a plurality of routers that form one of the segment routing paths **100** that has the segment routing path ID “103” have identifiers “11000,” “11021,” “11022” . . . .

The router group management data also indicates that a plurality of routers that form one of the segment routing paths **100** that has the segment routing path ID “221” have identifiers “12000,” “12001,” “12002” . . . . The router group management data also indicates that a plurality of routers that form one of the segment routing paths **100** that has the segment routing path ID “222” have identifiers “12000,” “12011,” “12012” . . . . The router group management data also indicates that a plurality of routers that form one of the segment routing paths **100** that has the segment routing path ID “223” have identifiers “12000,” “12021,” “12022” . . . “20001”.

In the example of FIG. **9**, the router that has the router ID “20001” is a component shared by three of the segment routing paths **100** that have the segment routing path IDs “011,” “102,” and “223.”

In the present embodiment, as described above, the slice manager **92**, the life cycle manager **94**, or the SDN controller **74** may change the segment routing paths **100** that are components of a network slice, or routers that are components of one of the segment routing paths **100**.

In the present embodiment, in response to such a change of components, the router group data (for example, the segment routing path management data shown in FIG. **8** or the router group management data shown in FIG. **9**) stored in the inventory database **82** is updated.

The segment routing paths **100** that are current components of a network slice or a group of routers that are current components of one of the segment routing paths **100** are accordingly identifiable by referring to the router group data.

In the present embodiment, for example, the monitor **72** monitors, for each of the plurality of function elements included in the communication system **1**, and for each network slice available to the function element, performance of the function element in slice communication that uses the network slice.

Specifically, the monitor **72** monitors, for example, performance of the gNB **102***a* in slice communication using the first network slice, performance of the gNB **102***a* in slice communication using the second network slice, performance of the qNB **102***a* in slice communication using the third network slice, performance of the gNB **102***b* in slice communication using the first network slice, performance of the gNB **102***b* in slice communication using the second network slice, performance of the qNB **102***b* in slice communication using the third network slice, performance of the gNB **102***c* in slice communication using the first network slice, performance of the gNB **102***c* in slice communication using the second network slice, and performance of the qNB **102***c* in slice communication using the third network slice.

In the present embodiment, the policy manager **90**, for example, then determines, for each of the plurality of function elements included in the communication system **1**, and for each network slice available to the function element, whether performance of the function element has deteriorated in slice communication using the network slice.

The policy manager **90** may repeatedly determine whether the performance of the function element has deteriorated in the slice communication. For example, the policy manager **90** may repeatedly determine whether the performance of the function element has deteriorated in the slice communication at a predetermined time interval (for example, an interval of 15 minutes).

For example, the monitor **72** may generate, at a predetermined time interval (for example, an interval of 15 minutes), for each network slice available to a function element, performance index value data indicating performance of the function element in slice communication using the network slice in the immediate last period of the predetermined length of time (for example, the last 15 minutes). The monitor **72** may output the generated performance index value data to the data bus **68** at the time interval.

In response to the output of the performance index value data to the data bus **68**, the policy manager **90** may acquire the output performance index value data. The policy manager **90** may determine, based on the performance index value data, whether the performance of the function element has deteriorated in the slice communication using the network slice. In such a manner, whether performance of a function element in slice communication has deteriorated may be determined at a predetermined time interval.

For example, in a case in which a larger value of the performance index value data indicates higher performance, the policy manager **90** may determine that performance of a function element in slice communication has deteriorated when a value of the latest performance index value data indicating the performance of the function element in the slice communication is smaller than a predetermined threshold value.

In a case in which a larger value of the performance index value data indicates lower performance, the policy manager **90** may determine that performance of a function element in slice communication has deteriorated when a value of the latest performance index value data indicating the performance of the function element in the slice communication is larger than a predetermined threshold value.

Examples of the performance indicated by the performance index value data include a bearer connection completion ratio, an abnormal disconnection count, and an abnormal disconnection ratio. A comprehensive value (for example, a linear combination value of a plurality of types of performance index values) calculated based on performance index values that indicate performance of a plurality of types (for example, the bearer connection completion ratio and the abnormal disconnection count) may be used as a value of the performance index value data. The performance indicated by the performance index value data is not limited to those described above, and may be, for example, a throughput or latency.

In the present embodiment, when, for example, it is determined for a plurality of function elements that performance of the function elements in slice communication has deteriorated, the policy manager **90** identifies a group of routers located on a route of the slice communication for each of the plurality of function elements, based on the router group data described above. As described above, the route may be a route on which packets are forwarded by segment routing.

The policy manager **90** may determine, for a plurality of function elements, at the same timing at a predetermined time interval, whether performance in slice communication has deteriorated. The policy manager **90** may then identify a plurality of function elements determined in the latest determination to have deteriorated in performance in slice communication.

The policy manager **90** may then identify, for each of the plurality of identified function elements, a group of routers located on a route of the slice communication.

In the present embodiment, the policy manager **90** then estimates, for example, at least one router that is included in every group of routers identified for each of the plurality of function elements determined to have deteriorated in performance, as a router that is a cause of the deterioration of performance of the function elements.

For example, it is assumed that performance of the gNB **102***a* is determined to have deteriorated in slice communication using the second network slice in the latest determination.

In such a case, for example, segment routing path IDs included in a segment routing path ID list that is linked to the function element ID "gNB001" and the slice ID "002" in the segment routing path management data are identified. The segment routing path IDs identified here are, for example, "011," "012," and "013."

For each of the thus identified segment routing path IDs, router IDs included in a router ID list that is linked to the segment routing path ID in the router group management data are identified.

Examples of the router ID list identified here include a router ID list that is linked to the segment routing path ID "011" in the router group management data, a router ID list that is linked to the segment routing path ID "012" therein, and a router ID list that is linked to the segment routing path ID "013" therein.

Router IDs included in at least one of the thus identified router ID lists are then identified. A group of router IDs including router IDs identified in such a manner is hereinafter referred to as "cause candidate router ID group." For example, "10000," "10001," "10002," "10011," "10012," "10021," "10022," "20001" . . . are identified here as a cause candidate router ID group linked to the gNB **102***a* and the second network slice.

Further, it is assumed that performance of the gNB **102***b* in slice communication using the first network slice is determined to have deteriorated in the latest determination.

In such a case, in the same manner, "11000," "11001," "11002," "11011," "11012," "11021," "11022," "20001" . . . are identified here as a cause candidate router ID group linked to the gNB **102***b* and the first network slice.

Further, it is assumed that performance of the gNB **102***c* in slice communication using the third network slice is determined to have deteriorated in the latest determination.

In such a case, in the same manner, "12000," "12001," "12002," "12011," "12012," "12021," "12022," "20001" . . . are identified here as a cause candidate router ID group linked to the gNB **102***c* and the third network slice.

The policy manager **90** then identifies at least one router ID that is included in every cause candidate router ID group identified in such a manner for each of the plurality of function elements determined to have deteriorated in performance in slice communication. The policy manager **90** then estimates a router identified by the identified router ID to be a router that is the cause of the deterioration of performance of the function elements.

Here, the cause candidate router ID group linked to the qNB **102***a* and the second network slice, the cause candidate router ID group linked to the gNB **102***b* and the first network slice, and the cause candidate router ID group linked to the gNB **102***c* and the third network slice are identified as described above.

In such a case, "20001," which is a router ID included in every one of the three cause candidate router ID groups, is thus estimated to be the router ID of a router that is the cause of the deterioration of performance of the function elements.

In the example described above, one router is estimated to be a router that is the cause of the deterioration of performance of the function elements for the sake of convenience of description. However, a plurality of routers may be estimated to be causes H deterioration of performance of function elements.

In the present embodiment, for example, the slice manager **92** may output, to the SDN controller **74**, for each of the one or the plurality of routers estimated to be the causes of the deterioration of performance of the function elements, a change instruction to change a communication route with respect to a network slice that includes the router as a component. The SDN controller **74** may follow the change instruction to execute a switch to a communication route created by the SDN controller **74**.

For example, the slice manager **92** may output, to the SDN controller **74** that is linked to the router estimated to be the cause of the deterioration of performance of the function elements, a change instruction to change a communication route linked to the router ID of the router. When receiving the change instruction, the SDN controller **74** may switch the communication route created by the SDN controller **74** to a communication route from which the router identified by the router ID is excluded (that is, a communication route that does not run through the router).

An administrator or the like of the platform system **30** may check, for each of the routers estimated to be the causes of the deterioration of performance of the function elements, whether the router is experiencing a trouble such as a failure or exceeding of a capacity. The administrator or the like of the platform system **30** may then output, to the SDN controller **74**, an instruction to exclude a router for which occurrence of a trouble has been confirmed from the communication route. When receiving the instruction, the SDN controller **74** may switch the communication route created by the SDN controller **74** to a communication route from which the router is excluded (that is, a communication route that does not run through the router).

The SDN controller **74** or the slice manager **92** may update the segment routing path management data shown in FIG. **8** and the router group management data shown in FIG. **9**, which are stored in the inventory database **82**, based on the switching of the communication routes.

There is a case in which, despite detection of no trouble in a router that is a component shared by a plurality of network slices included in the communication system **1** in the present embodiment, performance of a plurality of function elements deteriorates in communication that uses a network slice available to the function elements (so-called silent failure) as described above.

In the present embodiment, for each of a plurality of function elements determined to have deteriorated in performance in slice communication, a group of routers located on a route of the slice communication is identified as described above. At least one router included in every identified group of routers is then estimated to be a router that is the cause of the deterioration of performance of the function elements.

According to the present embodiment, a router that is a cause of a silent failure in a network slice can accurately be estimated in such a manner.

In the present embodiment, the policy manager **90** may determine, based on performance of a function element in slice communication at a given point in time and performance of the function element in the slice communication prior to the given point in time, whether the performance of the function element in the slice communication has deteriorated.

For example, a threshold value may be determined based on a value of past performance index value data. Whether the performance of the function element has deteriorated may be determined based on the determined threshold value.

For example, the AI **70** may calculate an expectation value (for example, a moving average value) and a standard deviation of a performance index value based on past performance index value data (for example, performance index value data in the immediate last period of a predetermined length of time) indicating performance of a function element in slice communication using a network slice. The expectation value and the standard deviation of the performance index value may be calculated with use of a trained machine learning model. The threshold value described above may be determined based on the calculated expectation value and standard deviation.

For example, a value obtained by adding a value that is twice the standard deviation of the performance index value to the expectation value of the performance index value may be determined to be the threshold value. In such a case, it may be determined that the performance of the function element in the slice communication has deteriorated when a value of the latest performance index value data indicating the performance of the function element in the slice communication is larger than the threshold value.

Further, for example, a value obtained by subtracting a value that is twice the standard deviation of the performance index value from the expectation value of the performance index value may be determined to be the threshold value. In such a case, it may be determined that the performance of the function element in the slice communication has deteriorated when a value of the latest performance index value data indicating the performance of the function element in the slice communication is smaller than the threshold value.

The AI **70** may determine a threshold value for each period type (for example, time of day or day of the week). For example, the AI **70** may calculate, based on performance index value data in a period belonging to a specified period type out of the immediate last period of a predetermined length of time, an expectation value and a standard deviation of a performance index value for the period type. The AI **70** may determine a threshold value for the period type based on the thus calculated expectation value and standard deviation of the performance index value with respect to the period type.

The policy manager **90** may then determine, based on performance of a function element in slice communication at a given point in time and performance of the function element in the slice communication prior to the given point in time with respect to the same period type as a period type to which the given point in time belongs, whether the performance of the function element in the slice communication has deteriorated. For example, it is assumed that a day of the week to which the given point in time belongs is Sunday. In such a case, whether performance of a function element has deteriorated may be determined based on a performance index value indicating performance of the function element in the slice communication at the given point in time and a threshold value for Sunday in the slice communication.

Determination of whether performance of a function element has deteriorated in light of past performance of the function element is accomplished in such a manner.

For example, the policy manager **90** may identify, for each of function elements determined at least once to have deteriorated in performance in slice communication out of the immediate last predetermined number of times determination is executed, a group of routers located on a route of the slice communication. At least one router included in every group of routers identified in such a manner may be estimated to be a router that is a cause of the deterioration of performance of the function elements.

For example, it is assumed that determination of whether performance of a function element in slice communication has deteriorated is executed at a predetermined time interval (for example, an interval of 15 minutes). In such a case, groups of routers may be identified for a plurality of function elements determined at least once to have deteriorated in performance in slice communication out of the immediate last four times the determination is executed (that is, determination executed 45 minutes ago, determination executed 30 minutes ago, determination executed 15 minutes ago, and determination executed at present).

With performance deterioration caused by one router, there may be a lag in timing at which performance deteriorates between function elements, depending on the distance from the router, for example. A router that is a cause of a silent failure in a network slice can accurately be estimated despite such a lag by identifying, as described above, groups of routers for function elements determined at least once to have deteriorated in performance out of the immediate last predetermined number of times the determination is executed.

The policy manager **90** may determine that performance of a function element in slice communication has deteriorated when a performance index value indicating the performance of the function element in the slice communication satisfies a predetermined condition for a predetermined period.

For example, it is assumed that whether a performance index value indicating performance of a function element in slice communication satisfies a predetermined condition (for example, whether the performance index value is smaller than a threshold value) is determined for every 15 minutes. In such a case, the performance of the function element in slice communication may be determined to have deteriorated when the performance index value in a period from 45 minutes ago to the present satisfies the predetermined condition (that is, when the performance index value is determined to satisfy the predetermined condition in three consecutive times of execution of determination).

In such a manner, a situation in which a function element is determined to have deteriorated in performance when the deterioration of performance is temporary and is not required to be dealt with can be avoided.

The performance manager **88** may generate, by aggregating the performance index value data generated by the monitor **72**, for each network slice available to a function element, overall performance index value data indicating performance of the function element in slice communication that uses the network slice. The policy manager **90** may determine, based on the overall performance index value data generated by the performance manager **88**, for each network slice available to a function element, whether performance of the function element in slice communication using the network slice has deteriorated.

In the present embodiment, the policy manager **90** may exclude routers located on a route of slice communication of a function element not determined to have deteriorated performance in the slice communication from routers estimated to be causes of deterioration of performance of a function element.

For example, it is assumed that the gNB **102***a* is not determined to have deteriorated in performance in slice communication using the first network slice. In such a case, routers included in a group of routers that are components of the segment routing paths **100** having the segment routing path IDs "001," "002," and "003" may be identified as routers to be excluded. When the routers to be excluded are included among routers estimated to be causes of deterioration of performance of a function element, the policy manager **90** may exclude the routers to be excluded from the routers estimated to be causes of deterioration of performance of a function element.

In such a manner, a router that is a cause of a silent failure in a network slice can be estimated more accurately.

In the examples given above, for each network slice available to function elements (the gNBs **102** in the examples described above) included in the RANs **32**, whether performance of function elements has deteriorated in slice communication using the network slice is determined. In such a case, groups of routers located on routes between the RANs **32** and the core network systems **34** (in the examples described above, routes between the gNBs **102** and the UPFs **50**) may be identified.

In the present embodiment, for each network slice available to function elements (for example, the UPFs **50**) included in the core network systems **34**, whether performance of function elements has deteriorated in slice communication using the network slice may be determined. Groups of routers located on routes between the RANs **32** and the core network systems **34** may then be identified. In such a case, whether performance of the UPFs **50** in slice communication using a network slice has deteriorated may be determined based on, for example, performance index values about the UPEs **50**.

The present invention is applicable also to estimation of a router that is a cause of a silent failure in a network slice in a route other than the routes between the RANs **32** and the core network systems **34**.

For example, a router that is a cause of a silent failure in a network slice in one of routes (midhaul) between the CUS **44** and the DUs **42** may be estimated.

In such a case, the policy manager **90** may determine, for each network slice available to one of the CUS **44**, whether performance of the CU **44** in slice communication using the network slice has deteriorated. The policy manager **90** may then identify, for each one of a plurality of CUs **44** that are determined to have deteriorated in performance in slice communication, a group of routers located on a route of the slice communication between the one of the CUs **44** and one of the DUs **42**. At least one router included in every router group identified in such a manner may be estimated to be a router that is a cause of the deterioration of performance of the CUS **44**.

A value of the performance index value data may be a value indicating performance of a function element on the user plane, or a value indicating performance of a function element on the control plane. In such a case, the bearer connection completion ratio, the abnormal disconnection count, and the abnormal disconnection ratio described above, for example, correspond to indices of performance of a function element on the user plane. Examples of indices of performance of a function element on the control plane include a registration success ratio.

In a case of determining whether performance of a function element on the user plane has deteriorated, a router that is a cause of the deterioration of performance of the function element may be estimated from a group of routers that are components of the user plane.

In a case of determining whether performance of a function element on the control plane has deteriorated, a router that is a cause of the deterioration of performance of the function element may be estimated from a group of routers that are components of the control plane.

A router that is a cause of deterioration of performance of a function element may be estimated from a group of routers that are components of the control plane and a group of routers that are components of the user plane even in determination about performance of a function element on the control plane.

It is not required to identify, for each of a plurality of function elements determined to have deteriorated in performance in slice communication, a group of routers including all routers located on a route of the slice communication. Instead, a group of routers that are components of one or a plurality of network slice subnet instances may be identified out of the group of routers located on the route of the slice communication. For example, a group of routers in a backhaul part on the route may be identified. To give another example, a group of routers in a midhaul part on the route may be identified.

An example of a flow of a process executed in the platform system **30** in the present embodiment to estimate a router that is a cause of deterioration of performance of a function element is described with reference to a flow chart exemplified in FIG. **10**.

First, the policy manager **90** determines, for each of the plurality of function elements included in the communication system **1**, and for each network slice available to the function element, whether performance of the function element in slice communication using the network slice has deteriorated (Step S**101**).

The policy manager **90** then identifies a plurality of function elements determined in the process step of Step S**101** to have deteriorated in performance in the slice communication (Step S**102**).

The policy manager **90** then identifies, for each of the plurality of function elements identified in the process step of Step S**102**, a group of routers located on a route of the slice communication (Step S**103**).

At least one router included in every group of routers identified in the process step of Step S**103** is then estimated to be the router that is the cause of the deterioration of performance of the plurality of function elements identified in the process step of Step S**102** (Step S**104**). Then, the process illustrated in the process example is ended.

It should be noted that the present invention is not limited to the above-mentioned embodiment.

For example, the functional unit in the present embodiment is not limited to those illustrated in FIG. **3**.

Further, the functional unit in the present embodiment is not required to be an NF in 5G. For example, the functional unit in the present embodiment may be an eNodeB, a vDU, a vCU, a packet data network gateway (P-GW), a serving gateway (S-GW), a mobility management entity (MME), a home subscriber server (HSS), or another network node in 4G.

Further, roles divided among the functions illustrated in FIG. **5** are not limited to those described above.

Further, the functional unit in the present embodiment may be implemented through use of a hypervisor-type or host-type virtualization technology instead of the container-type virtualization technology. Further, the functional unit in the present embodiment is not required to be implemented by software, and may be implemented by hardware, for example, by an electronic circuit. Further, the functional unit in the present embodiment may be implemented by a combination of an electronic circuit and software.

The technology described in the present disclosure can also be expressed as follows.

[1]

A router estimation system, including:

router group data storing means that stores, for each one of a plurality of network slices constructed in a communication system, router group data indicating a group of routers that form the each one of the plurality of network slices;

determination means that determines, for each one of a plurality of function elements included in the communication system, and for each network slice available to the each one of the plurality of function elements, whether performance of the each one of the plurality of function elements in slice communication using the each network slice has deteriorated;

router group identification means that identifies, when a plurality of function elements out of the plurality of function elements included in the communication system are determined to have deteriorated in performance in the slice communication, for each of the plurality of function elements determined to have deteriorated in performance, a group of routers located on a route of the slice communication, based on the router group data; and

router estimation means that estimates at least one router included in every router group identified for the each of the plurality of function elements determined to have deteriorated in performance to be a router that is a cause of the deterioration of performance of the plurality of function elements.

[2]

The router estimation system according to Item [1], wherein the determination means determines that the each one of the plurality of function elements has deteriorated in performance in the slice communication when a performance index value indicating performance of the each one of the plurality of function elements in the slice communication satisfies a predetermined condition for a predetermined period.

[3]

The router estimation system according to Item [1] or [2], wherein the determination means repeatedly determines whether performance of the each one of the plurality of function elements in the slice communication has deteriorated, and

wherein the router group identification means identifies the group of routers for each one of the plurality of function elements determined at least once to have deteriorated in performance out of an immediate last predetermined number of times the determination is executed.

[4]

The router estimation system according to any one of Items [1] to [3], wherein the router estimation means excludes, for each function element not determined to have deteriorated in performance in the slice communication out of the plurality of function elements included in the communication system, routers located on a route of the slice communication from routers estimated to be causes of deterioration of performance of the plurality of function elements.

[5]

The router estimation system according to any one of Items [1] to [4], wherein the determination means determines whether performance of the each one of the plurality of function elements in the slice communication has deteriorated based on performance of the each one of the plurality of function elements in the slice communication at a given point in time and performance of the each one of the plurality of function elements in the slice communication prior to the given point in time.

[6]

The router estimation system according to Item [5], wherein the determination means determines whether performance of the each one of the plurality of function elements in the slice communication has deteriorated based on performance of the each one of the plurality of function elements in the slice communication at a given point in time and performance of the each one of the plurality of function elements in the slice communication prior to the given point in time with respect to the same period type as a period type to which the given point in time belongs.

[7]

The router estimation system according to any one of Items [1] to [6], wherein the determination means determines, for each function element included in a radio access network of the communication system out of the plurality of function elements included in the communication system, and for each network slice available to the each function element, whether performance of the each function element in slice communication using the each network slice has deteriorated, and

wherein the router group identification means identifies the group of routers located on a route between the radio access network and a core network system of the communication system.

[8]

The router estimation system according to any one of Items [1] to [6],

wherein the determination means determines, for each function element included in a core network system of the communication system out of the plurality of function elements included in the communication system, and for each network slice available to the each function element, whether performance of the each function element in slice communication using the each network slice has deteriorated, and

wherein the router group identification means identifies the group of routers located on a route between the core network system and a radio access network of the communication system.

[9]

The router estimation system according to any one of Items [1] to [6],

wherein the determination means determines, for each network slice available to a central unit (CU), whether performance of the CU in slice communication using the each network slice has deteriorated, and

wherein the router group identification means identifies the group of routers located on a route between the CU and a distributed unit (DU) included in the communication system.

[10]

The router estimation system according to any one of Items [1] to [9], wherein the route is a route on which a packet is forwarded by segment routing.

[11]

The router estimation system according to any one of Items [1] to [10], wherein the each one of the plurality of function elements is a network service or a network function.

[12]

A router estimation method, including:

storing, for each one of a plurality of network slices constructed in a communication system, router group data indicating a group of routers that form the each one of the plurality of network slices;

determining, for each one of a plurality of function elements included in the communication system, and for each network slice available to the each one of the plurality of function elements, whether performance of the each one of the plurality of function elements in slice communication using the each network slice has deteriorated;

identifying, when a plurality of function elements out of the plurality of function elements included in the communication system are determined to have deteriorated in performance in the slice communication, for each of the plurality of function elements determined to have deteriorated in performance, a group of routers located on a route of the slice communication, based on the router group data; and

estimating at least one router included in every router group identified for the each of the plurality of function elements determined to have deteriorated in performance to be a router that is a cause of the deterioration of performance of the plurality of function elements.

The invention claimed is:

1. A router estimation system, comprising one or more processors, the router estimation system causing at least one of the one or more processors to execute:

a router group data storing process of storing, for each one of a plurality of network slices constructed in a communication system, router group data indicating a group of routers that form the each one of the plurality of network slices;

a determination process of determining, for each one of a plurality of function elements included in the communication system, and for each network slice available to the each one of the plurality of function elements, whether performance of the function elements in slice each one of the plurality of communication using the each network slice has deteriorated;

a router group identification process of identifying, when a plurality of function elements out of the plurality of function elements included in the communication system are determined to have deteriorated in performance in the slice communication, for each of the plurality of function elements determined to have deteriorated in performance, a group of routers located on a route of the slice communication, based on the router group data; and

a router estimation process of estimating at least one router included in every router group identified for the each of the plurality of function elements determined to have deteriorated in performance to be a router that is a cause of the deterioration of performance of the plurality of function elements.

2. The router estimation system according to claim **1**, wherein, in the determination process, the each one of the plurality of function elements is determined to have deteriorated in performance in the slice communication when a performance index value indicating performance of the each one of the plurality of function elements in the slice communication satisfies a predetermined condition for a predetermined period.

3. The router estimation system according to claim **1**,

wherein, in the determination process, whether performance of the each one of the plurality of function elements in the slice communication has deteriorated is repeatedly determined, and

wherein, in the router group identification process, the group of routers is identified for each one of the plurality of function elements determined at least once to have deteriorated in performance out of an immediate last predetermined number of times the determination is executed.

4. The router estimation system according to claim **1**, wherein, in the router estimation process, for each function element not determined to have deteriorated in performance in the slice communication out of the plurality of function elements included in the communication system, routers located on a route of the slice communication are excluded from routers estimated to be causes of deterioration of performance of the plurality of function elements.

5. The router estimation system according to claim 1, wherein, in the determination process, whether performance of the each one of the plurality of function elements in the slice communication has deteriorated is determined based on performance of the each one of the plurality of function elements in the slice communication at a given point in time and performance of the each one of the plurality of function elements in the slice communication prior to the given point in time.

6. The router estimation system according to claim 5, wherein, in the determination process, whether performance of the each one of the plurality of function elements in the slice communication has deteriorated is determined based on performance of the each one of the plurality of function elements in the slice communication at a given point in time and performance of the each one of the plurality of function elements in the slice communication prior to the given point in time with respect to the same period type as a period type to which the given point in time belongs.

7. The router estimation system according to claim 1,

wherein, in the determination process, for each function element included in a radio access network of the communication system out of the plurality of function elements included in the communication system, and for each network slice available to the each function element, whether performance of the each function element in slice communication using the each network slice has deteriorated is determined, and

wherein, in the router group identification process, the group of routers located on a route between the radio access network and a core network system of the communication system is identified.

8. The router estimation system according to claim 1,

wherein, in the determination process, for each function element included in a core network system of the communication system out of the plurality of function elements included in the communication system, and for each network slice available to the each function element, whether performance of the each function element in slice communication using the each network slice has deteriorated is determined, and

wherein, in the router group identification process, the group of routers located on a route between the core network system and a radio access network of the communication system is identified.

9. The router estimation system according to claim 1,

wherein, in the determination process, for each network slice available to a central unit (CU), whether performance of the CU in slice communication using the each network slice has deteriorated is determined, and

wherein, in the router group identification process, the group of routers located on a route between the CU and a distributed unit (DU) included in the communication system is identified.

10. The router estimation system according to claim 1, wherein the route is a route on which a packet is forwarded by segment routing.

11. The router estimation system according to claim 1, wherein the each one of the plurality of function elements is a network service or a network function.

12. A router estimation method, comprising:

storing, for each one of a plurality of network slices constructed in a communication system, router group data indicating a group of routers that form the each one of the plurality of network slices;

determining, for each one of a plurality of function elements included in the communication system, and for each network slice available to the each one of the plurality of function elements, whether performance of the each one of the plurality of function elements in slice communication using the each network slice has deteriorated;

identifying, when a plurality of function elements out of the plurality of function elements included in the communication system are determined to have deteriorated in performance in the slice communication, for each of the plurality of function elements determined to have deteriorated in performance, a group of routers located on a route of the slice communication, based on the router group data; and

estimating at least one router included in every router group identified for the each of the plurality of function elements determined to have deteriorated in performance to be a router that is a cause of the deterioration of performance of the plurality of function elements.

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