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(54) **Title:** METHODS, SYSTEMS, AND COMPUTER READABLE MEDIA FOR DIAMETER ROUTING USING SOFTWARE DEFINED NETWORK (SDN) FUNCTIONALITY

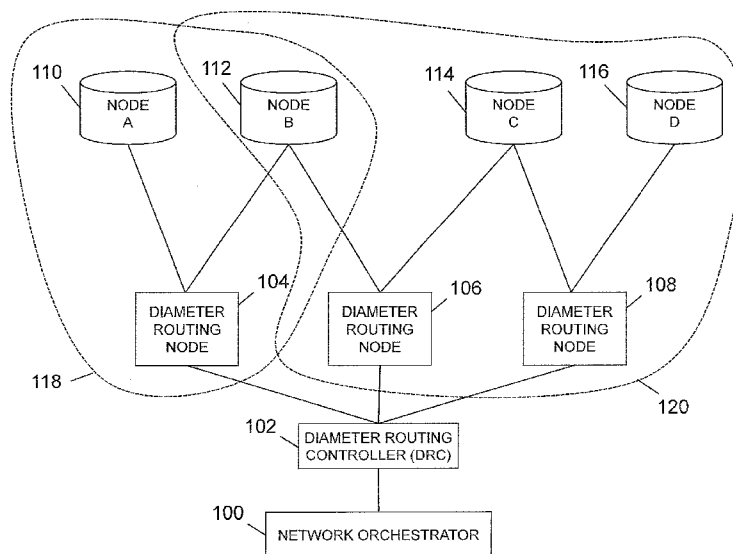


FIG. 1

(57) **Abstract:** Methods, systems, and computer readable media for routing a Diameter message are disclosed. According to one method, the method occurs at a Diameter routing node. The method includes receiving, from a Diameter routing controller (DRC) via a software defined network (SDN) related interface, Diameter routing information, wherein the Diameter routing information is determined using application layer information. The method also includes routing a Diameter message using the Diameter routing information.

DESCRIPTION

METHODS, SYSTEMS, AND COMPUTER READABLE MEDIA FOR
DIAMETER ROUTING USING SOFTWARE DEFINED NETWORK (SDN)
FUNCTIONALITY

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PRIORITY CLAIM

This application claims the benefit of U.S. Patent Application Serial No. 14/092,898, filed November 27, 2013, the disclosure of which is incorporated herein by reference in its entirety.

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TECHNICAL FIELD

The subject matter described herein relates to determining policy information. More specifically, the subject matter relates to methods, systems, and computer readable media for Diameter routing using software defined network (SDN) functionality.

15

BACKGROUND

In telecommunications networks, global Internet protocol traffic is increasing at a rate of forty to fifty percent per year. In order to retain subscribers, it is desirable for service providers to keep monthly charges to subscribers relatively unchanged. Keeping charges constant with increasing traffic requires a reduction in expenses. For example, with a forty percent increase in traffic, service providers must reduce capital expenses and operational expenses by forty to fifty percent per gigabyte per second per year to achieve relatively constant pricing.

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One possible method for reducing capital and operational expenses is to use software defined networks (SDNs). SDNs can be used to manage flows, control switches, control network access, and track user location and motion. SDNs can also be used to efficiently utilize network components. For example, SDNs may be used to power off unused equipment during non-peak periods to conserve energy.

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Some SDN models may centralize the control of network elements, such as routers and switches, by removing intelligence from the routers and

switches and placing that intelligence in a centralized location. One such effort to provide centralized control of routers and switches is the OpenFlow architecture described in the OpenFlow Switch Specification, Version 1.1.0, February 28, 2011, the disclosure of which is incorporated herein by reference in its entirety. Conventionally, SDN architecture has not been used to control telecommunications network elements.

Accordingly, a need exists for methods, systems, and computer readable media for Diameter routing using SDN functionality.

10 SUMMARY

Methods, systems, and computer readable media for routing a Diameter message are disclosed. According to one method, the method occurs at a Diameter routing node. The method includes receiving, from a Diameter routing controller (DRC) via an SDN related interface, Diameter routing information, wherein the Diameter routing information is determined using application layer information. The method also includes routing a Diameter message using the Diameter routing information.

According to one system, the system includes a Diameter routing node. The Diameter routing node comprises an SDN related interface configured to receive, from a DRC, Diameter routing information, wherein the Diameter routing information is determined using application layer information. The Diameter routing node also includes a routing module configured to route a Diameter message using the Diameter routing information.

The subject matter described herein may be implemented in software in combination with hardware and/or firmware. For example, the subject matter described herein may be implemented in software executed by a processor. In one exemplary implementation, the subject matter described herein may be implemented using a computer readable medium having stored thereon computer executable instructions that when executed by the processor of a computer control the computer to perform steps. Exemplary computer readable media suitable for implementing the subject matter described herein include non-transitory devices, such as disk memory

devices, chip memory devices, programmable logic devices, and application specific integrated circuits. In addition, a computer readable medium that implements the subject matter described herein may be located on a single device or computing platform or may be distributed across multiple devices
5 or computing platforms.

As used herein, the term "node" refers to a physical computing platform including one or more processors and memory.

As used herein, the terms "function" or "module" refer to hardware, firmware, or software in combination with hardware and/or firmware for
10 implementing features described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter described herein will now be explained with reference to the accompanying drawings of which:

15 Figure 1 is a diagram illustrating exemplary SDN components according to an embodiment of the subject matter described herein;

Figure 2 is a diagram illustrating an exemplary DRC and an exemplary Diameter routing node (DRN) according to an embodiment of the subject matter described herein;

20 Figures 3A and 3B are diagrams illustrating exemplary Diameter routing information according to an embodiment of the subject matter described herein;

Figure 4 is a diagram illustrating exemplary messages associated with routing a Diameter message according to an embodiment of the subject
25 matter described herein;

Figure 5 is a diagram illustrating exemplary messages associated with providing Diameter information about one or more newly available Diameter resources according to an embodiment of the subject matter described herein; and

30 Figure 6 is a diagram illustrating an exemplary process for routing a Diameter message according to an embodiment of the subject matter described herein.

DETAILED DESCRIPTION

The subject matter described herein discloses methods, systems, and computer readable media for Diameter routing using SDN functionality. Diameter is an authentication, authorization, and accounting (AAA) application layer protocol for computer networks, and is a successor to RADIUS. The Diameter base protocol is defined in IETF RFC 6733, the disclosure of which is incorporated by reference herein in its entirety. Diameter communications may use a request-answer message exchange. Diameter routing involves routing of request messages in one direction and answer messages in the reverse direction.

In accordance with some aspects of the subject matter described herein, a Diameter routing node may use SDN functionality and/or SDN components. For example, a Diameter router node (e.g., a Diameter routing agent (DRA) or Diameter signaling router (DSR)) may communicate with a Diameter routing controller (DRC). In this example, the Diameter routing node may receive routing decisions and/or Diameter routing information from the DRC. In some embodiments, the DRC and the Diameter routing node may communicate using an SDN related interface, such as an OpenFlow protocol interface or a Diameter protocol interface.

In accordance with some aspects of the subject matter described herein, a Diameter routing node may route Diameter messages without performing application layer (e.g., open systems interconnection (OSI) model layer 7) analysis. For example, an initial Diameter request message may be received by a Diameter routing node. The Diameter routing node may query a DRC (e.g., via an SDN related interface) for Diameter routing information associated with the Diameter request message. In this example, the Diameter routing information may include an Internet protocol (IP) address and/or port information associated with a destination node. The Diameter routing node may associate Diameter routing information received from the DRC (e.g., via an SDN related interface) and non-application layer information associated with the Diameter message (e.g., an IP data tuple associated with an IP packet containing the Diameter message). For example, an IP data tuple may include a source IP address, a destination IP

address, a source port number, a destination port number, and/or a transport protocol. In this example, the IP data tuple may be usable to identify related Diameter session or flows and may be referred to as a session data flow (SDF) filters. Using an IP data tuple or other information, the Diameter
5 routing node may identify and route related Diameter messages to the same destination node indicated by the previously received Diameter routing information, e.g., without querying the DRC or performing application layer analysis on the related Diameter messages.

Advantageously, by using SDN functionality and/or SDN components,
10 a Diameter routing node may route Diameter messages while conserving resources, e.g., resources typically used when performing application layer processing. By querying and receiving routing decisions and/or Diameter routing information via an SDN related interface, a Diameter routing node in accordance with aspects of the subject matter described herein may
15 conserve more resources than a conventional Diameter routing node.

Additionally, by using SDN functionality and/or SDN components, information about newly (e.g., recently) available Diameter resources may be provided to a Diameter routing node. For example, Diameter routing information about a newly available Diameter network node (e.g., a Diameter
20 application server) may be provided to a Diameter routing node, thereby allowing the Diameter routing node to dynamically route Diameter messages to the newly available Diameter resource.

Reference will now be made in detail to exemplary embodiments of the subject matter described herein, examples of which are illustrated in the
25 accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts.

Figure 1 is a diagram illustrating exemplary SDN components according to an embodiment of the subject matter described herein. In some embodiments, various nodes may be associated with or controlled by SDN
30 functionality. Referring to Figure 1, exemplary SDN components may include a network orchestrator **100**, a DRC **102**, Diameter routing node (DRN) **104-108**, and/or nodes **110-116**. Network orchestrator **100** may represent any suitable entity (e.g., software executing on a processor) for

monitoring network events and/or hardware events. For example, network orchestrator **100** may communicate with various entities (e.g., various nodes, network operators, or other sources) and may determine whether a node, a resource, or a network segment is overloaded, experiencing problems, or operating normally. Network orchestrator **100** may use received or derived information to predict future conditions (e.g., network congestion or node failures). Network orchestrator **100** may include functionality for allocating or reallocating various network resources, such as Diameter resources (e.g., Diameter network functions, Diameter nodes, or resources at Diameter functions or nodes), based on monitored or predicted conditions. For example, network orchestrator **100** may include virtualization functionality for dynamically allocating or reallocate hardware resources associated with a physical device and for instantiating needed resource instances using hardware associated with the physical device.

DRC 102 may represent any suitable entity (e.g., software executing on a processor) for performing Diameter routing decisions and/or providing Diameter routing information. For example, **DRC 102** may communicate with one or more of **DRNs 104-108** via an SDN related interface. Exemplary SDN related interfaces may include an OpenFlow protocol interface or a Diameter protocol interface. **DRC 102** may receive Diameter messages or related information from one or more of **DRNs 104-108**. **DRC 102** may determine an appropriate destination for received Diameter messages, e.g., by analyzing or inspecting application layer information (e.g., a Diameter realm identifier (ID), a Diameter command code, a Diameter node name, etc.) associated with the Diameter messages. **DRC 102** may provide Diameter routing information to one or more of **DRNs 104-108**, e.g., via an SDN related interface. Exemplary Diameter routing information may include address information and/or other identifying information associated with a destination, such as an IP address and/or port information, a uniform resource identifier (URI), a fully qualified domain name (FQDN), or other information.

Each of **DRNs 104-108** may represent any suitable entity (e.g., software executing on a processor) for routing Diameter signaling messages.

For example, each of DRNs **104-108** may be an LTE signaling router, an LTE Diameter signaling router, a Diameter proxy, a Diameter agent, a Diameter routing agent, a Diameter relay agent, Diameter translation agent, or a Diameter redirect agent. Each of DRNs **104-108** may include
5 functionality for processing various messages. In some embodiments, such functionality may be included in one or more modules (e.g., a firewall module, a network address translation (NAT) module, a subscriber location module, and/or a routing module). It will be appreciated that functionality and modules as used herein refers to hardware, software, firmware, or any
10 combination of hardware, software, and firmware for implementing the features described herein.

Each of DRNs **104-108** may include functionality for receiving, processing, and/or switching or routing various messages and may include various communications interfaces for communicating with Diameter nodes,
15 e.g., 3rd Generation Partnership Project (3GPP) LTE communications interfaces and other (e.g., non-LTE) communications interfaces. Exemplary communications interfaces for communicating with Diameter nodes may include an LTE interface, an IMS interface, an IETF specification interface, a 3GPP specification interface, a Third Generation Partnership Project 2
20 (3GPP2) specification interface, a European Telecommunications Standards Institute (ETSI) specification interface, an International Telecommunications Union (ITU) specification interface, a PacketCable specification interface, a MultiService Forum (MSF) specification interface, an Sh interface, a Dx interface, a Ro interface, a Rf interface, an Sp interface, a Gx interface, a Rx interface, a Gz interface, a Gy interface, a Gq interface, a Zh interface, a Dz
25 interface, a Zn interface, a Ty interface, a Tx interface, a Dw interface, a Wa interface, a Wd interface, a Wx interface, a Wm interface, a Wg interface, a Pr interface, a Gr interface, a Gr+ interface, a Gi interface, a Wo interface, a Wf interface, a Re interface, an S6 interface, an S2 interface, an SW interface, an Sta interface, an S7 interface, an H2 interface, an E2 interface,
30 an E4 interface, an E5 interface, a A3 interface, a A4 interface, a Rr interface, a Gq' interface, a TC-6 interface, a TC-7 interface, a TC-8 interface, a TC-9 interface, a TC-10 interface, a TC-11 interface, a DB-0

interface, a DB-2 interface, a BI-1 interface, a LOC-1 interface, an Rw interface, a Pkt-mm-2 interface, a P-CSCF-PAM interface, a Pkt-laes-2 interface, an MM10 interface, an MZ interface, a Gmb interface, or a Zn' interface.

5 Each of DRNs **104-108** may include functionality for receiving, processing, and/or switching or routing SDN related messages and may include various communications interfaces for communicating with SDN related nodes or components, e.g., a Diameter protocol interface or an OpenFlow protocol interface.

10 In some embodiments, each of DRNs **104-108** may be configurable for communicating with DRC **102** and/or network orchestrator **100**, e.g., via an SDN related interface. For example, DRN **104** may request or query DRC **102** for Diameter routing information. DRC **102** may determine appropriate Diameter routing information and provide the Diameter routing
15 information to DRN **104**. In response to receiving the Diameter routing information, DRN **104** may store the Diameter routing information in a local or otherwise accessible routing table and may use the Diameter routing information for routing Diameter messages. In another example, DRN **104** may provide statistics or other status information to network orchestrator
20 **100**. Network orchestrator **100** may use the information to direct, provision, or control DRN **104**, DRC **102**, and/or other nodes, e.g., by triggering DRC **102** to provide Diameter routing information to DRN **104** or by sending SDN related commands directly to DRN **104**.

 In some embodiments, SDN related messages (e.g., from DRC **102**
25 or network orchestrator **100**) may be solicited (e.g., by DRN **104** sending a request message) or may be unsolicited (e.g., an SDN related message may be sent to DRN **104** for provisioning a Diameter routing table without a corresponding request message from DRN **104**).

 Each of DRNs **104-108** may facilitate communication between
30 Diameter clients and Diameter servers. For example, a Diameter client may send a Diameter request message (e.g., a Diameter session establishment request message) to DRN **108**. The Diameter request message may require one or more services from a Diameter server. DRN **108** may route, relay,

and/or translate requests or responses between the Diameter client and the Diameter server. After receiving and processing the Diameter request message, the Diameter server may send a Diameter response message (e.g., a Diameter session establishment response message) to DRN **108**.

- 5 The Diameter response message may be sent in response to the Diameter request message originated by the Diameter client. DRN **108** may provide the Diameter response message to the Diameter client, e.g., using Diameter routing information.

Each of nodes **110-116** may represent any suitable entity (e.g., software executing on a processor) capable of communicating using a Diameter-based protocol. For example, each of nodes **110-116** may be a Diameter client, a Diameter server, a mobility management entity (MME), a home subscriber server (HSS), an authentication, authorization, and/or accounting (AAA) server, a Diameter application server, a subscriber profile repository (SPR), or other Diameter node. Each of nodes **110-116** may include functionality for processing various messages. For example, nodes **110-116** may represent a plurality of HSSs, where each HSS contains subscriber-related information, such as user identification, control information for user authentication and authorization, location information, and user profile data.

In some embodiments, DRNs **104-108** and nodes **110-116** may be associated with SDNs **118** and **120**. Each of SDN **118** and **120** may represent a network containing one or more nodes (or virtual nodes). For example, network orchestrator **100** may allocate or trigger allocation of resources (e.g., using DRC **102**) and configure resources such that DRN **104** is associated with SDN **118** and DRNs **106** and **108** are associated with SDN **120**. In this example, DRC **102** may provide Diameter routing information or configure routing table data such that DRN **104** routes Diameter messages to nodes **110** and **112**, while DRC **102** may provide Diameter routing information or configure routing table data such that DRNs **106** and **108** route Diameter messages to nodes **112**, **114**, and **116**.

It will be appreciated that Figure 1 is for illustrative purposes and that various nodes, their locations, and/or their functions described above in

relation to Figure 1 may be changed, altered, added, or removed. For example, some nodes and/or functions may be combined into a single entity, e.g., network orchestrator **100** and DRC **102** may be included in a single policy and charging rules function (PCRF) node or a single Diameter Routing Agent (DRA) node. In a second example, a node and/or function may be located at or implemented by two or more nodes, e.g., DRC **102** may be distributed across multiple nodes for handling multiple SDNs **118** and **120**.

Figure 2 is a diagram illustrating exemplary DRC **102** and exemplary DRN **104** according to an embodiment of the subject matter described herein. In some embodiments, DRC **102** and DRC **104** may be configurable to include multiple logical nodes, modules, or functions.

Referring to Figure 2, DRC **102** may include a policy-based Diameter routing agent (PDRA) controller **200** and an offline charging system (OFCS) controller **202**. PDRA controller **200** may represent any suitable entity for determining and/or providing Diameter routing information. PDRA controller **200** may include or access a PCRF. For example, PDRA controller **200** may use policy information provided by a PCRF in determining policy decisions. In this example, policy information may include policy and charging control (PCC) rules and may indicate that certain subscribers receive enhanced services or features. Using policy information, PDRA controller **200** may route Diameter messages associated with a particular subscriber or session to an appropriate destination.

OFCS controller **202** may represent any suitable entity for determining and/or providing charging related information. OFCS controller **202** may include or access a charging trigger function (CTF), a charging data function (CDF), and/or a charging gateway function (CGF). For example, OFCS controller **202** may determine how a subscriber, session, or service should be charged or billed. In this example, charging information may be provided to DRN **104** or logical Diameter router **206** such that a particular session can be billed appropriately, e.g., without requiring DRN **104** to perform its own OFCS related analysis.

DRN **104** may include logical Diameter routers **204** and **206**. For example, each of logical Diameter routers **204** and **206** may use physical

resources associated with DRN **104**. Each of logical Diameter routers **204** and **206** may include modules, memory, and/or other components associated with routing Diameter messages. For example, logical Diameter router **204** may include a routing module **208**, an SDN interface **210**, and a
5 Diameter routing table **212** and logical Diameter router **206** may include a routing module **214**, an SDN interface **216**, and a Diameter routing table **218**.

Each of routing modules **208** and **214** may represent any suitable entity for routing Diameter messages. For example, routing module **208** or
10 routing module **214** may use one or more physical interfaces for receiving and/or sending Diameter messages and may include functionality for routing a Diameter message to a destination using Diameter routing information, e.g., received via SDN interface **210** and/or stored in Diameter routing table **212**.

15 Each of SDN interfaces **210** and **216** may represent any suitable entity for receiving and/or sending SDN related messages. For example, SDN interface **210** or SDN interface **216** may include one or more physical interfaces for communicating with DRC **102**, PDRA controller **200**, OFCS controller **202**, or network orchestrator **100**.

20 Each of Diameter routing tables **212** and **218** may represent any suitable entity (e.g., a non-transitory computer readable medium) for storing or maintaining Diameter routing information. For example, Diameter routing tables **212** and **218** may include associations between Diameter sessions, Diameter services or applications, or subscriber IDs and network node
25 address information.

Figure 3A is a diagram illustrating exemplary Diameter routing information **300** according to an embodiment of the subject matter described herein. In some embodiments, exemplary routing data **300** may be accessed and/or stored by DRNs **104**, **106**, and/or **108** using various data
30 structures.

Referring to Figure 3A, Diameter routing information **300** may include associations between subscriber IDs and network node address information and may be depicted using a table. The routing table of Figure 3A may

include a subscriber ID field, a network node URI field, a network node FQDN field, and a network node IP address field. Subscriber ID field may include subscriber or device identifiers (or portions thereof), such as an international mobile subscriber identity (IMSI), a mobile subscriber integrated
5 services digital network (MSISDN) number, a short code, a URI, IMEI, and a mobile identification number (MIN). Network node URI, FQDN, and IP address fields represents fields for storing address information or routing information for nodes.

As depicted in Figure 3A, Diameter routing information **300** may
10 indicate an association between an IMSI (e.g., IMSI value: "310012353464342") and a network node associated with a URI (e.g., URI value: "aaa://host.example.com:1813;transport=udp;protocol=radius"). Diameter routing information **300** may also indicate a second association between a portion of an IMSI (e.g., IMSI portion value: "314024*") and a
15 network node associated with a URI (e.g., URI value: "hss://hss1.vzw.net:1815;transport=udp;protocol=radius;protocol=radius"), an FQDN (e.g., FQDN value: "HSS1@VZW.NET"), and an IP address (e.g., IP address value: "192.53.34.11 port number: 1815"). By using a portion of an IMSI followed by a wildcard "*" character, the second association may
20 indicate a group of subscribers (e.g., subscribers having the same initial 6 digits for their IMSI values) that are associated with a particular node. Diameter routing information **300** may also indicate a third association between a portion of an IMSI (e.g., IMSI portion value: "220412353464342") and a network node associated with an IP address (e.g., IP address value:
25 "192.23.43.12 port number: 64"). Diameter routing information **300** may also indicate other associations between IMSIs or portions thereof and one or more network node identifiers for identifying associated nodes.

In some embodiments, Diameter routing information **300** may indicate associations between Diameter sessions and network nodes. For example,
30 a first Diameter session may be associated with first node, while a second session may be associated with a second node. In some embodiments, Diameter routing information **300** may indicate associations between Diameter services or applications and network nodes. For example, a

registration service may be associated with a first node, while a credit control service may be associated with a second node.

In some embodiments, DRC **102** and/or network orchestrator **100** may provide Diameter routing information **300** to DRNs **104**, **106**, and/or **108**. For example, using SDN related interfaces and/or related messages, DRC **102** may configure or provision Diameter routing table **212** using various factors, e.g., current load of a resource or network segment, predicted load of a resource or network segment, resource problems, a new resource becoming available, a resource becoming unavailable, a time of day, subscriber or device issues, or other factors. By providing Diameter routing information **300** and/or provisioning Diameter routing tables, DRC **102** and/or network orchestrator **100** may dynamically adjust current or predicted network conditions and/or may modify SDN boundaries (e.g., by including additional nodes as possible destinations for Diameter messages or by removing nodes as possible destinations for Diameter messages).

Referring to Figure 3B, Diameter routing information **302** may represent Diameter routing information **300** that is modified after one or more SDN related messages from DRC **102** and/or network orchestrator **100**. The routing table of Figure 3B may include similar or identical fields as the routing table of Figure 3A. As depicted in Figure 3B, Diameter routing information **302** may be modified to route Diameter messages to different network nodes than indicated by Diameter routing information **300**. For example, Diameter routing information **302** may include an association between a portion of an IMSI (e.g., IMSI portion value: "314024*") and a network node associated with a URI (e.g., URI value: "hss://hss3.vzw.net:1815;transport=udp; protocol=radius"), an FQDN (e.g., FQDN value: "HSS3@VZW.NET"), and an IP address (e.g., IP address value: "192.53.34.41 port number: 1815"). Diameter routing information **302** may also include an association between a portion of an IMSI (e.g., IMSI portion value: "458712353468745") and a network node associated with a URI (e.g., URI value: "hss://hss4.vzw.net:1815;transport=udp;protocol=radius"), an FQDN (e.g.,

FQDN value: "HSS4@VZW.NET"), and an IP address (e.g., IP address value: "192.53.34.42 port number: 1815").

It will be appreciated that Diameter routing information **300** and **302** may vary depending on the communications network, configuration, messages, and network nodes involved. For example, types of addressing or routing information may vary for network nodes. In another example, Diameter routing information **300** and **302** may include network layer address information for identifying a network node in lieu of a FQDN or URI.

In some embodiments, each association may be between a subscriber ID or a Diameter session or service and address information associated with a particular network node. In such embodiments, multiple entries may be used to identify additional nodes.

In some embodiments, each association may be between a subscriber ID or a Diameter session or service and one or more associated nodes (e.g., backup or secondary node addresses). In such embodiments, additional fields (e.g., backup node fields) may be used to identify additional nodes.

In some embodiments, Diameter routing information **300** or Diameter routing information **302** may include one or more status fields for identifying whether an associated node is currently available, experiencing problems, or inactive.

Figure 4 is a diagram illustrating exemplary messages associated with routing a Diameter message according to an embodiment of the subject matter described herein. In some embodiments, node **110** may be an HSS for maintaining subscriber location information pertaining to a subset of network subscribers. In some embodiments, MME **300** may be an MME for managing mobility events associated with one or more subscribers.

Referring to Figure 4, at step **1**, a mobility management message may be received at a MME **300**. In some embodiments, the received mobility management message may be a registration message referred to as a tracking area update (TAU) message. The TAU message or registration message may be initiated by a user device when the user device detects entering a tracking area that is not previously registered in MME **300** for use

by the user device. The TAU message may include UE-related information, such as an IMSI or other device identifier.

At step 2, in response to receiving the mobility management message, a Diameter message may be generated and sent from MME 300 to DRN 104. For example, MME 300 may generate and send an Update-Location-Request (ULR) message in response to receiving the TAU message. The ULR message may include various parameters, such as the IMSI value associated with the TAU message.

In some embodiments, MME 300 may not determine or may be unable to provide address information or routing information for sending the Diameter message to an appropriate destination. DRN 104 may be configured to receive and route such messages to appropriate destinations.

In some embodiments, DRN 104 may receive a ULR message sent by MME 300. DRN 104 may examine the received Diameter message and may determine whether and/or how to route the message. For example, network orchestrator 100 may allocate or otherwise nodes 110-116 in a communications network to distribute or reduce processing load on any particular one of nodes 110-116. In this example, if nodes 110-116 do not include identical data, it may be necessary to identify the node that contains a particular subscriber's data when attempting to route messages.

In some embodiments where subscribers or sessions are handled by a plurality of nodes 110-116, DRN 104 may query accessible Diameter routing information (e.g., stored in a local Diameter routing table) for determining an appropriate destination. In some embodiments, querying accessible Diameter routing information may involve using non-application layer information (e.g., an IP data tuple) associated with a Diameter message that is to be routed.

In some embodiments, DRN 104 may be unable to determine addressing or routing information. For example, if an appropriate destination is not found in accessible Diameter routing information, DRN 104 may be capable of requesting Diameter routing information from other nodes, such as DRC 102 or network orchestrator 100 via an SDN related interface.

At step 3, an SDN related message for requesting Diameter routing information may be sent from DRN 104 to DRC 102. For example, DRN 104 may request Diameter routing information from DRC 102 by sending a route information request message via an SDN related interface. The route information request message may include various information associated with the corresponding Diameter message, such as a subscriber identifier and/or session related information.

In some embodiments, DRC 102 may receive a route information request message and may use information stored in the route information request message for determining an appropriate destination. For example, DRC 102 may analyze application layer information, such as Diameter identifiers, stored in the route information request message to determine an appropriate destination.

At step 4, an SDN related message for providing Diameter routing information may be sent from DRC 102 to DRN 104. For example, DRC 102 may provide Diameter routing information to DRN 104 by sending a route information answer message via an SDN related interface. After receiving Diameter routing information from DRC 102, DRN 104 may store the Diameter routing information and may use this information for routing Diameter messages.

In some embodiments, using Diameter routing information provided by DRC 102, DRN 104 may determine an appropriate destination, e.g., node 110, for a Diameter message. After determining an appropriate destination for a received Diameter message, DRN 104 may modify the Diameter message, e.g., to include the destination information, prior to routing the Diameter message.

At step 5, the Diameter message may be sent from DRN 104 to node 110. For example, DRN 104 may send a modified ULR message to node 110.

In some embodiments, node 110 may receive a Diameter message and respond. For example, in response to receiving an ULR message, node 110 may send an Update-Location-Answer (ULA) message indicating that location information was received and stored.

At step **6**, a Diameter answer message may be sent from node **110** to MME **300**. For example, DRN **104** may send a ULA message to node **110**.

At step **7**, a second mobility management message may be received at a MME **300**. In some embodiments, the second mobility management message may be a TAU message indicating that a user device is entering a tracking area that is not previously registered in the MME **300** for use by the user device. The TAU message may include UE-related information, such as an IMSI or other device identifier.

At step **8**, in response to receiving the mobility management message, a Diameter message may be generated and sent from MME **300** to DRN **104**. For example, MME **300** may generate and send an Update-Location-Request (ULR) message in response to receiving the TAU message. The ULR message may include various parameters, such as the IMSI value associated with the TAU message.

DRN **104** may examine the received Diameter message and may determine whether and/or how to route the message. For example, DRN **104** may query accessible Diameter routing information (e.g., stored in a local Diameter routing table) for determining an appropriate destination. In some embodiments, querying accessible Diameter routing information may involve using non-application layer information associated with the Diameter message.

Using accessible Diameter routing information (e.g., previously provided by DRC **102**), DRN **104** may determine an appropriate destination, e.g., node **110**, for a Diameter message. After determining an appropriate destination for a received Diameter message, DRN **104** may modify the Diameter message, e.g., to include the destination information, prior to routing the Diameter message.

At step **9**, the Diameter message may be sent from DRN **104** to node **110**. For example, DRN **104** may send a modified ULR message to node **110**.

In some embodiments, node **110** may receive a Diameter message and respond. For example, in response to receiving an ULR message, node

110 may send an Update-Location-Answer (ULA) message indicating that location information was received and stored.

It will also be appreciated that the above described messages are for illustrative purposes and that different and/or additional messages may be used.

Figure 5 is a diagram illustrating exemplary messages associated with providing Diameter information about one or more newly available Diameter resources according to an embodiment of the subject matter described herein. In some embodiments, network orchestrator **100** may be configured to instantiate, allocate, or make available one or more Diameter resources (e.g., a Diameter network function or node or additional resources for an existing function or node). For example, network orchestrator **100** may instantiate Diameter resources dynamically (e.g., in response to monitored information, network conditions, or a request from a network node) or statically (e.g., based on preconfigured instructions or directives). In such embodiments, network orchestrator **100** may provide relevant information, such as Diameter routing information, about newly available Diameter resources to DRC **102** or DRN **104** and/or other nodes. By providing the relevant information to DRC **102**, Diameter destinations associated with the newly available Diameter resources may be added to a Diameter routing table at DRC **102**. DRC **102** may then communicate the Diameter destinations to DRN **104**, whereby DRN **104** may use this information to route Diameter messages, readjust load balancing algorithm(s), or readjust failure handling algorithm(s) to the newly available Diameter resources.

Referring to Figure 5, at step **500**, network orchestrator **100** may allocate or instantiate one or more Diameter resources, e.g., for use in a Diameter-based network. For example, network orchestrator **100** may determine that one or more additional Diameter resources (e.g., HSS5@VZW.NET) may be useful for handling an increase in Diameter traffic associated with a particular SDN or portion therein. In this example, network orchestrator **100** may use received information, from other external system, such as another orchestrator or monitoring system, about

components in the SDN and/or other relevant information in determining to make available additional Diameter resources.

At step **501**, an SDN related message for providing Diameter routing information, or information appropriate for that diameter function, may be sent from network orchestrator **100** to DRC **102**. For example, a Diameter routing table (DRT) provisioning message may be sent from network orchestrator **100** to DRC **102**. The DRT provisioning message may include Diameter routing information about a newly available Diameter resource, e.g., the Diameter routing information may include a network node FQDN and/or an IP address and port information. In this example, DRC **102** may use the included Diameter routing information to update a Diameter routing table.

At step **502**, an SDN related message for acknowledging reception of Diameter routing information may be sent from DRC **102** to network orchestrator **100**. For example DRC **102** may send a DRT provisioning answer message indicating that Diameter routing information was successfully received.

At step **503**, a Diameter ULR message may be generated and sent to DRN **104**. For example, MME **300** may generate and send a ULR message in response to receiving a TAU message. The ULR message may include various parameters, such as the IMSI value associated with the TAU message.

In some embodiments, DRN **104** may be unable to determine addressing or routing information. For example, if an appropriate destination is not found in accessible Diameter routing information, DRN **104** may be capable of requesting Diameter routing information from other nodes, such as DRC **102** or network orchestrator **100** via an SDN related interface.

At step **504**, an SDN related message for requesting Diameter routing information may be sent from DRN **104** to DRC **102**. For example, DRN **104** may request Diameter routing information from DRC **102** by sending a route information request message via an SDN related interface. The route information request message may include various information associated

with the corresponding Diameter message, such as a subscriber identifier and/or session related information.

In some embodiments, DRC **102** may receive a route information request message and may use information stored in the route information request message for determining an appropriate destination. For example, DRC **102** may analyze application layer information, such as Diameter identifiers, stored in the route information request message and may determine that a newly available Diameter resource is an appropriate destination.

At step **505**, an SDN related message for providing Diameter routing information may be sent from DRC **102** to DRN **104**. For example, DRC **102** may provide Diameter routing information to DRN **104** by sending a route information answer message via an SDN related interface. The route information answer message may include Diameter routing information about a newly available Diameter resource (e.g., HSS5@VZW.NET). After receiving Diameter routing information from DRC **102**, DRN **104** may store the Diameter routing information and/or may use this information for routing Diameter messages to the newly available Diameter resource.

In some embodiments, DRN **104** may modify the Diameter message, e.g., to include the Diameter routing information received from DRC **102**, prior to routing the Diameter message to the newly available Diameter resource.

It will also be appreciated that the above described messages are for illustrative purposes and that different and/or additional messages may be used. For example, network orchestrator **100** may communicate Diameter routing information to DRN **102** directly (e.g., without using DRC **102**). In this example, network orchestrator **100** may send a DRT provisioning message to DRN **104** and DRN **104** may respond with a DRT provisioning answer message to network orchestrator. In another example, DRC **102** may provide Diameter routing information about a newly available Diameter resource to a DRN **102** unilaterally (e.g., automatically or without DRN **104** requesting routing information).

Figure 6 is a diagram illustrating an exemplary process **600** for routing a Diameter message according to an embodiment of the subject matter described herein. In some embodiments, exemplary process **600**, or portions thereof, may be performed by or at DRN **104**, DRN **106**, DRN **108**,
5 DRC **102**, network orchestrator **100**, routing module **208**, routing module **214**, logical Diameter router **204**, logical Diameter router **206**, PDRA controller **200**, OFCS controller **202**, and/or another node or module. In some embodiments, exemplary process **600** may include steps **602** and/or **604**.

10 At step **602**, Diameter routing information may be received from DRC **102** via an SDN related interface (e.g., SDN interface **210**). In some embodiments, the Diameter routing information may be determined using application layer information, e.g., a Diameter realm identifier, a Diameter control code, a Diameter service or application identifier, and/or a Diameter
15 node URI or FQDN.

In some embodiments, Diameter routing information may include switching information (e.g., layer 2 and/or layer 3 information). In such embodiments, routing a Diameter message using Diameter routing information may include switching the Diameter message using the switching
20 information

In some embodiments, Diameter routing information may be received in response to the DRN **104** querying DRC **102** for the Diameter routing information after receiving a Diameter request message for initiating a Diameter session or an initial Diameter message.

25 In some embodiments, DRN **104** may use previously obtained Diameter routing information for routing Diameter message. For example, after receiving Diameter routing information for a particular session from DRC **102**, DRN **104** may receive a second Diameter message associated with the Diameter session and may route the second Diameter message
30 using the Diameter routing information associated with that particular session.

In some embodiments, Diameter router information may be received in response to network orchestrator **100** or DRC **102** determining that DRN

104 should receive the Diameter routing information based on a current condition or a predicted future condition.

In some embodiments, an SDN related interface may include an OpenFlow protocol interface, a network virtualization using generic routing encapsulation (NVGRE) protocol interface, a virtual extensible LAN (VXLAN) protocol interface, a forwarding and control element separation (ForCES) protocol interface, a locator/ID separation protocol (LISP) interface, an open vSwitch database management (OVSDB) protocol interface, a border gateway protocol (BGP) interface, a BGP link-state (BGP-LS) protocol interface, a path computation element protocol (PCEP) interface, a network configuration (NETCONF) protocol interface, a simple network management protocol (SNMP) interface, or a Diameter protocol interface. For example, SDN related interface may be used for communicating between DRC **102** and DRN **104**.

In some embodiments, DRC **102** may include a PCRF, an OFCS, and/or network orchestrator **100**. For example, DRC **102** may be capable of determining routing decisions based on policy information, subscriber credit information, and/or various network conditions.

In some embodiments, DRC **102** may be configured to communicate with network orchestrator **100**. In such embodiments, network orchestrator **100** may be configured to monitor or predict network conditions and may allocate or reallocate various network resources based on the monitored or the predicted network conditions.

In some embodiments, Diameter routing information may include address information associated with a destination node or a second Diameter routing node, layer 2 information, layer 3 information, layer 4 information, layer 5 information, layer 6 information, layer 7 information, switching information, an IP address, port information, Diameter application layer information, a Diameter realm ID, a Diameter command code, a Diameter node name, a URI, and/or an FQDN.

At step **602**, a Diameter message may be routed using the Diameter routing information. For example, DRN **104** may route a Diameter message

to node **110** using address information determined and provided by DRC **102**.

5 It will be understood that various details of the subject matter described herein may be changed without departing from the scope of the subject matter described herein. Furthermore, the foregoing description is for the purpose of illustration only, and not for the purpose of limitation, as the subject matter described herein is defined by the claims as set forth hereinafter.

CLAIMS

What is claimed is:

1. A method for routing a Diameter message, the method comprising:
at a Diameter routing node:
5 receiving, from a Diameter routing controller (DRC) via a software defined network (SDN) related interface, Diameter routing information, wherein the Diameter routing information is determined using application layer information; and
routing a Diameter message using the Diameter routing
10 information.
2. The method of claim 1 wherein the Diameter routing information includes switching information and wherein routing the Diameter message using the Diameter routing information includes switching the Diameter message using the switching information.
15 3. The method of claim 1 or claim 2 wherein the Diameter routing information is received in response to the Diameter routing node querying the DRC for the Diameter routing information after receiving a Diameter request message for initiating a Diameter session. The method of claim 1 or claim 2 wherein the Diameter
20 router information is received in response to a network orchestrator or the DRC determining that the Diameter routing node should receive the Diameter routing information based on a current condition or a predicted future condition.
4. The method of any of the preceding claims comprising:
25 receiving a second Diameter message associated with the Diameter session; and
5. routing the second Diameter message using the Diameter routing information. The method of any of the preceding claims wherein the
SDN related interface includes an OpenFlow protocol interface, a
30 network virtualization using generic routing encapsulation (NVGRE) protocol interface, a virtual extensible LAN (VXLAN) protocol interface, a forwarding and control element separation (ForCES) protocol interface, a locator/ID separation protocol (LISP) interface,

- an open vSwitch database management (OVSDb) protocol interface, a border gateway protocol (BGP) interface, a BGP link-state (BGP-LS) protocol interface, a path computation element protocol (PCEP) interface, a network configuration (NETCONF) protocol interface, a simple network management protocol (SNMP) interface, or a Diameter protocol interface.
- 5
6. The method of any of the preceding claims wherein the DRC includes a policy and charging rules function (PCRF), an offline charging system (OFCS), or a network orchestrator.
- 10
7. The method of any of the preceding claims wherein the DRC is configured to communicate with a network orchestrator, wherein the network orchestrator is configured to monitor or predict network conditions and allocate or reallocate various network resources based on the monitored or the predicted network conditions.
- 15
8. The method of any of the preceding claims wherein the Diameter routing information includes address information associated with a destination node or a second Diameter routing node, layer 2 information, layer 3 information, layer 4 information, layer 5 information, layer 6 information, layer 7 information, switching information, an Internet protocol (IP) address, port information, a uniform resource identifier (URI), Diameter application layer information, a Diameter realm identifier (ID), a Diameter command code, a Diameter node name, or a fully qualified domain name (FQDN).
- 20
9. A system for routing a Diameter message, the system comprising:
- 25
- a Diameter routing node comprising:
- a software defined network (SDN) related interface configured to receive, from a Diameter routing controller (DRC), Diameter routing information, wherein the Diameter routing information is determined using application layer information; and
- 30
- a routing module configured to route a Diameter message using the Diameter routing information.

10. The system of claim 9 wherein the Diameter routing information includes switching information and wherein the routing module is configured to switch the Diameter message using the switching information.
- 5 11. The system of claim 9 or claim 11 wherein the Diameter routing node is configured to receive, prior to receiving the Diameter routing information, a Diameter request message for initiating a Diameter session and to query the DRC for the Diameter routing information.
- 10 12. The system of claim 9 or claim 11 wherein a network orchestrator or the DRC is configured to determine that the Diameter routing node should receive the Diameter routing information based on a current condition or a predicted future condition.
- 15 13. The system of any of claims 9 to 13 wherein the Diameter routing node is configured to receive a second Diameter message associated with the Diameter session and to route the second Diameter message using the Diameter routing information. The system of any of claims 9 to 14 wherein the SDN related interface includes an OpenFlow protocol interface, a network virtualization using generic routing encapsulation (NVGRE) protocol interface, a virtual extensible LAN (VXLAN) protocol interface, a forwarding and control element separation (ForCES) protocol interface, a locator/ID separation protocol (LISP) interface, an open vSwitch database management (OVSDB) protocol interface, a border gateway protocol (BGP) interface, a BGP link-state (BGP-LS) protocol interface, a path computation element protocol (PCEP) interface, a network configuration (NETCONF) protocol interface, a simple network management protocol (SNMP) interface, or a Diameter protocol interface.
- 20 25 30 14. The system of any of claims 9 to 15 wherein the DRC includes a policy and charging rules function (PCRF), an offline charging system (OFCS), or a network orchestrator.
15. The system of any of claims 9 to 16 wherein the DRC is configured to communicate with a network orchestrator, wherein the network

orchestrator is configured to monitor or predict network conditions and allocate or reallocate various network resources based on the monitored or the predicted network conditions.

- 5 16. The system of any of claims 9 to 17 wherein the Diameter routing information includes address information associated with a destination node or a second Diameter routing node, layer 2 information, layer 3 information, layer 4 information, layer 5 information, layer 6 information, layer 7 information, switching information, an Internet protocol (IP) address, port information, a uniform resource identifier (URI), Diameter application layer information, a Diameter realm identifier (ID), a Diameter command code, a Diameter node name, or a fully qualified domain name (FQDN).
- 10
- 15 17. A non-transitory computer readable medium comprising computer executable instructions embodied in the computer readable medium that when executed by a processor of a computer control the computer to perform steps comprising:
- 20 receiving, from a Diameter routing controller (DRC) via a software defined network (SDN) related interface, Diameter routing information, wherein the Diameter routing information is determined using application layer information; and
- routing a Diameter message using the Diameter routing information.
- 25 18. A non-transitory computer readable medium according to claim 19 comprising computer executable instructions embodied in the computer readable medium that when executed by a processor of a computer control the computer to perform a method according to any of claims 1 to 9.

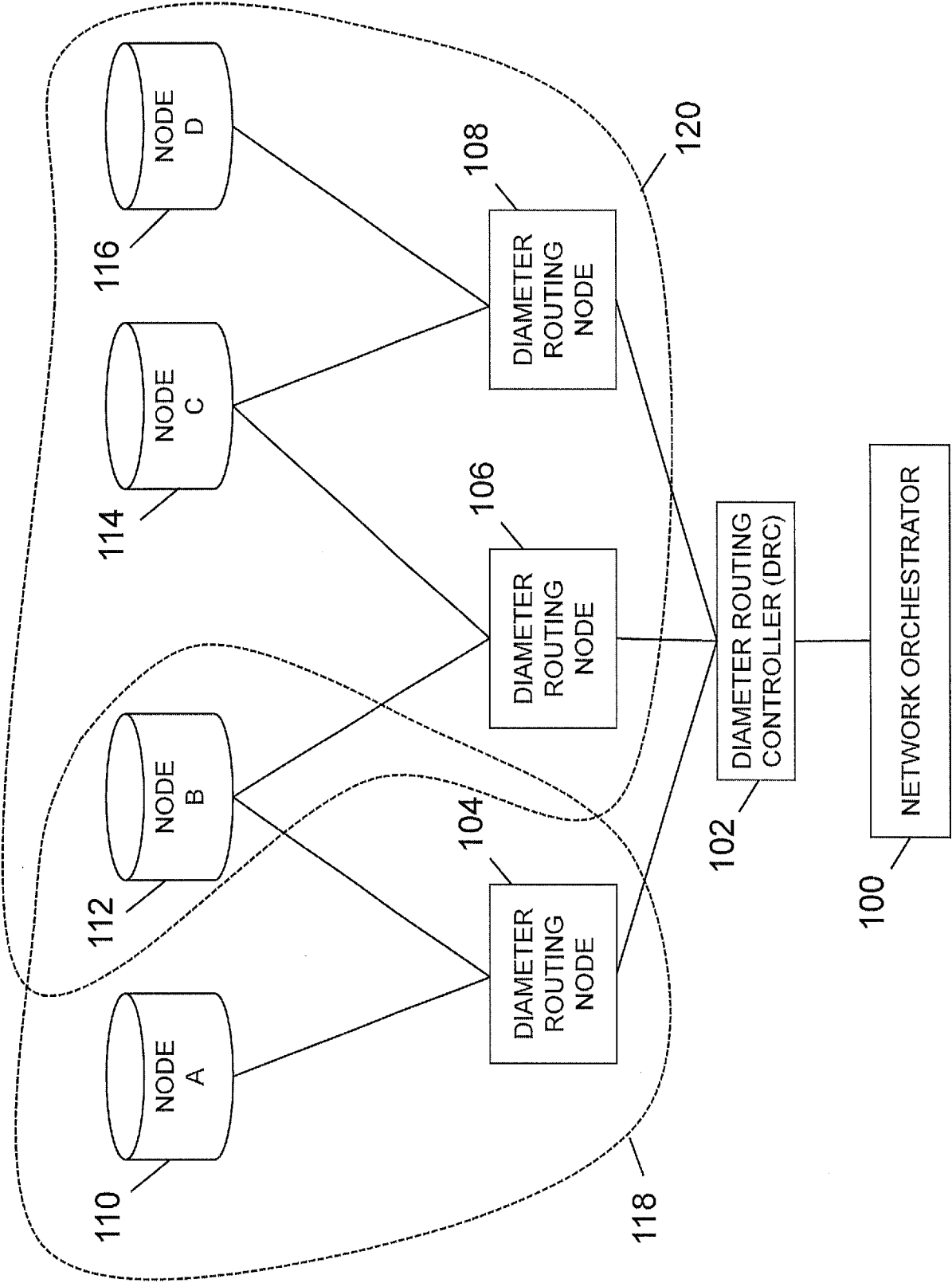


FIG. 1

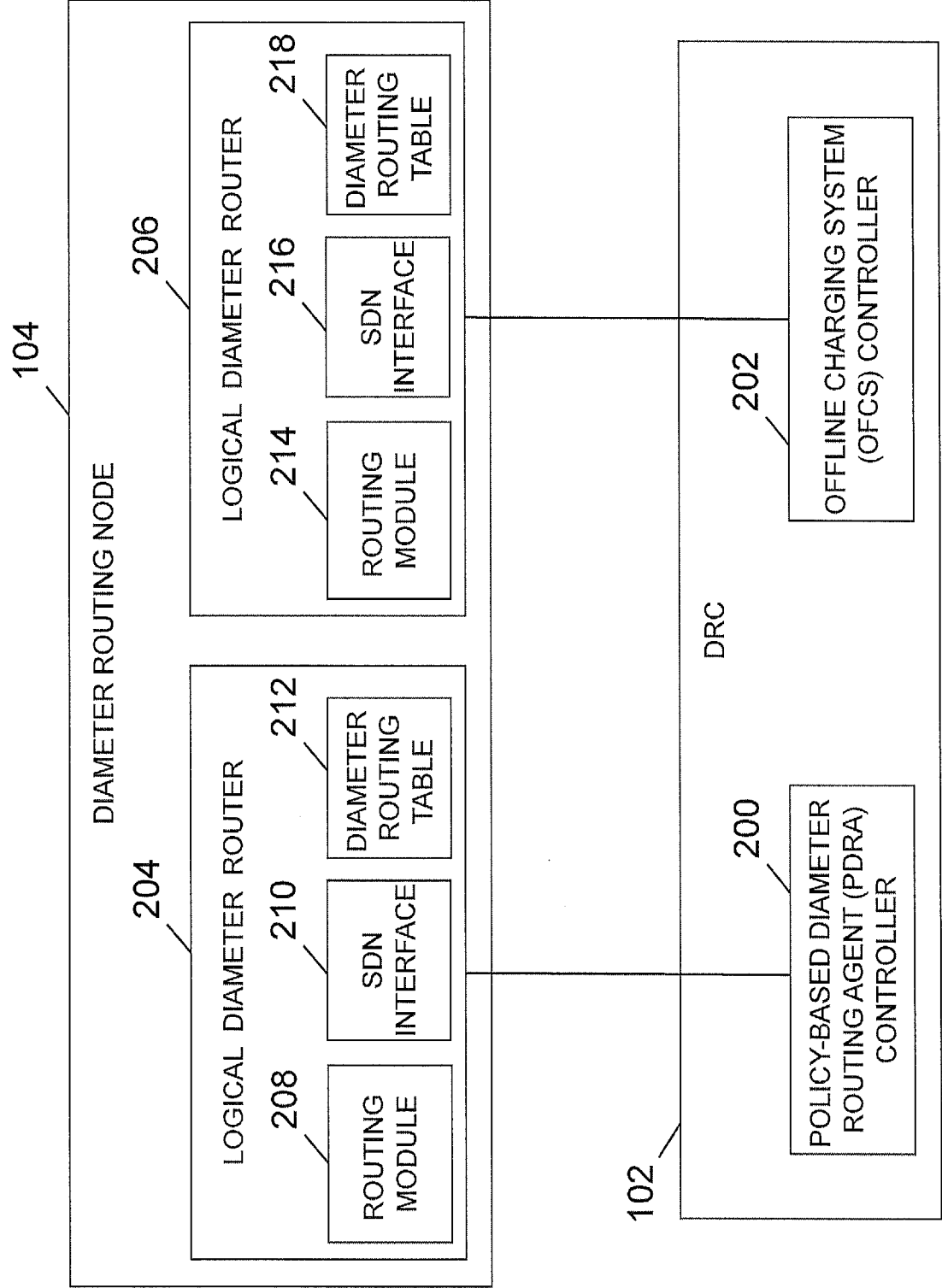


FIG. 2

ROUTING TABLE DATA

SUBSCRIBER ID	NETWORK NODE URI	NETWORK NODE FQDN	NETWORK NODE IP ADDRESS
310012353464342	aaa://host.example.com:1813;transport=udp;protocol=radius		
314024*	hss://hss1.vzw.net:1815;transport=udp;protocol=radius	HSS1@VZW.NET	192.53.34.11 PORT 1815
220412353464342			192.23.43.12 PORT 64
458712353468745	hss://hss2.vzw.net:1815;transport=udp;protocol=radius	HSS2@VZW.NET	192.53.34.12 PORT 1815
876452353487454		GW@SPRINT.NET	194.25.23.4 PORT 534
567534*	fgw://pdngw3.att.com:1819;transport=udp;protocol=diameter	PDNGW3.@ATT.COM	

300

FIG. 3A

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ROUTING TABLE DATA

SUBSCRIBER ID	NETWORK NODE URI	NETWORK NODE FQDN	NETWORK NODE IP ADDRESS
310012353464342	aaa://host.example.com:1813;transport=udp;protocol=radius		
314024*	hss://hss3.vzw.net:1815;transport=udp;protocol=radius	HSS3@VZW.NET	192.53.34.41 PORT 1815
220412353464342			192.23.43.12 PORT 64
458712353468745	hss://hss4.vzw.net:1815;transport=udp;protocol=radius	HSS4@VZW.NET	192.53.34.42 PORT 1815
876452353487454		GW@SPRINT.NET	194.25.23.4 PORT 534
567534*	fgw://pdngw3.att.com:1819;transport=udp;protocol=diameter	PDNGW3.ATT.COM	

302

FIG. 3B

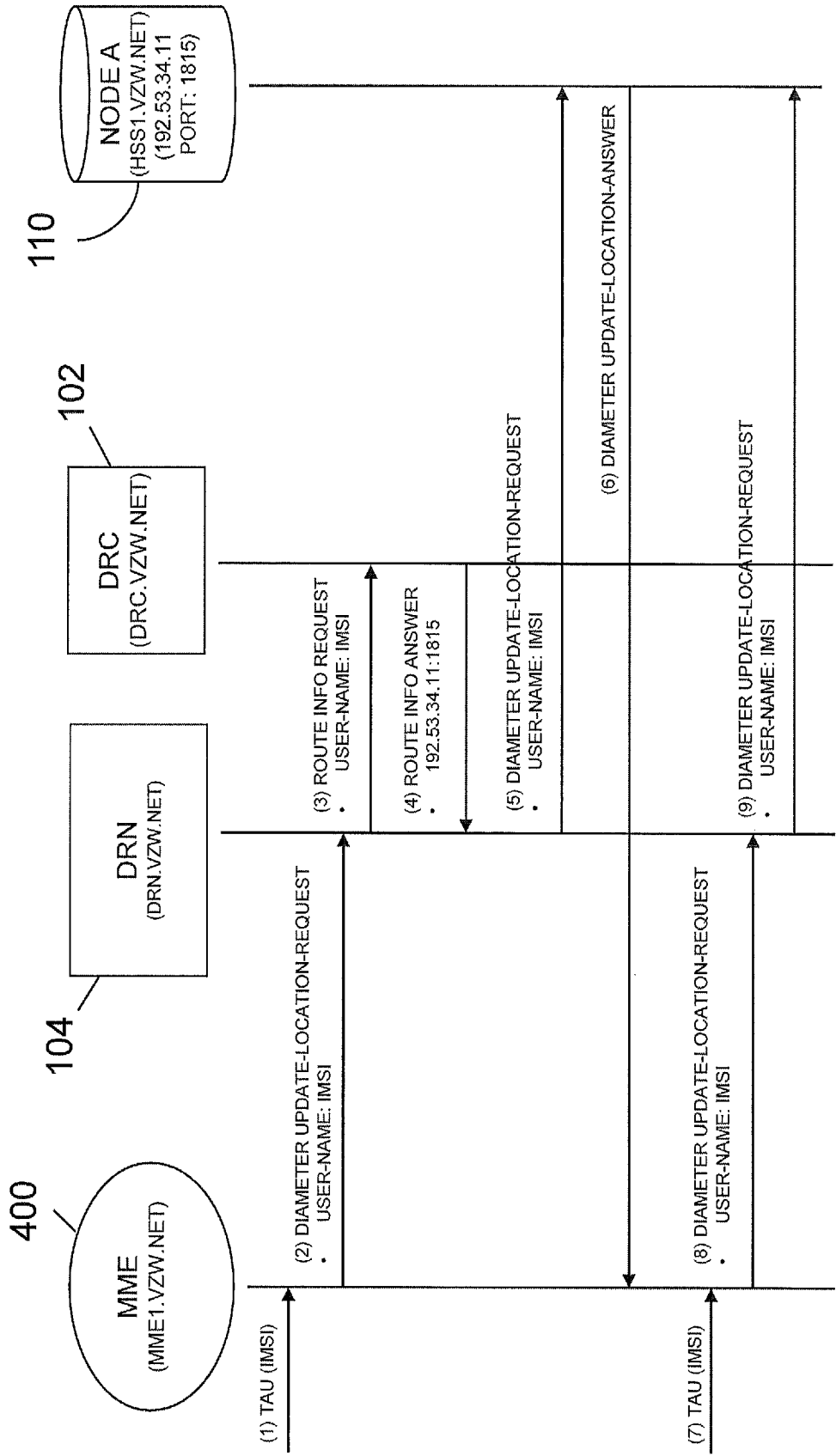


FIG. 4

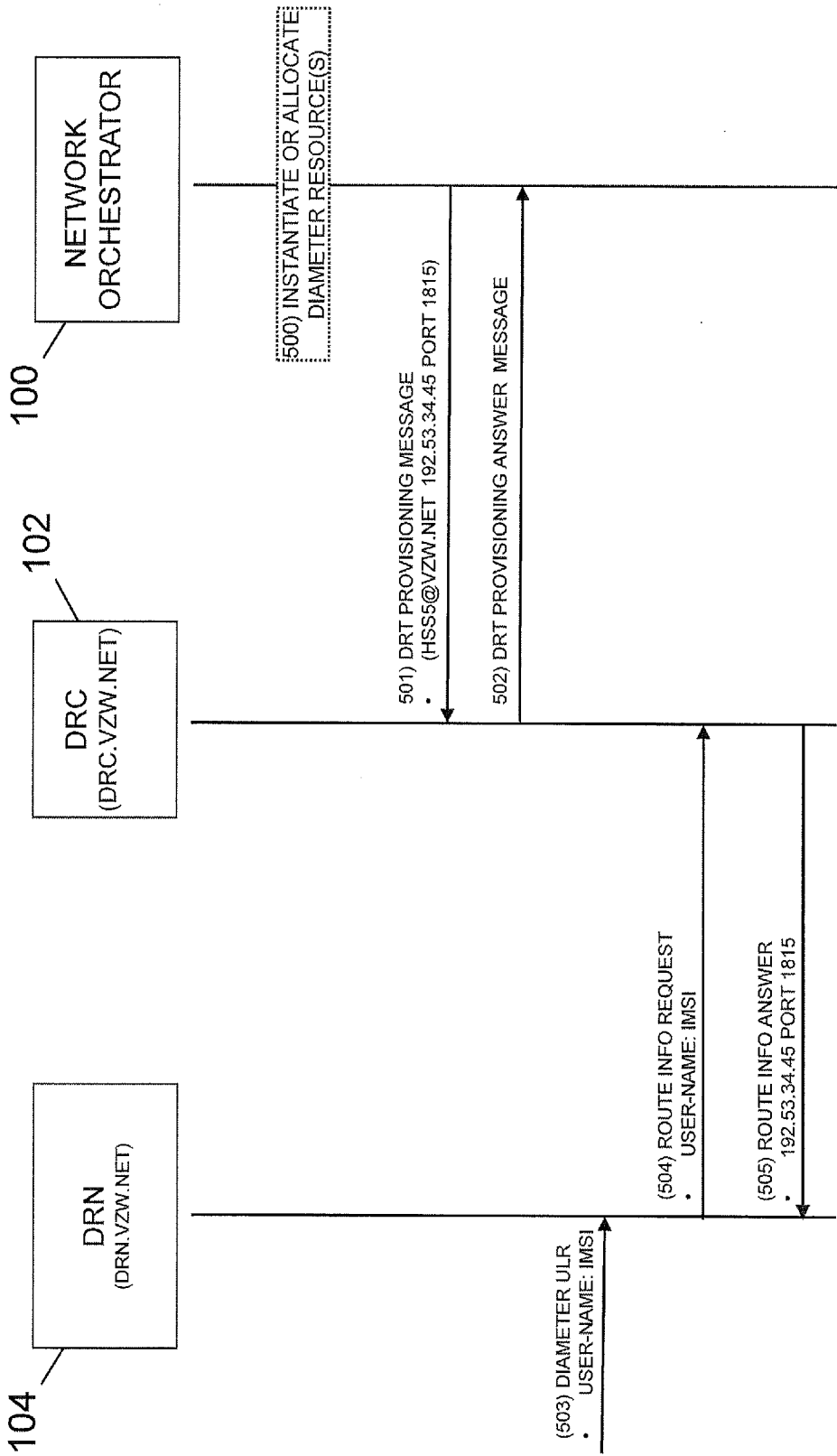


FIG. 5

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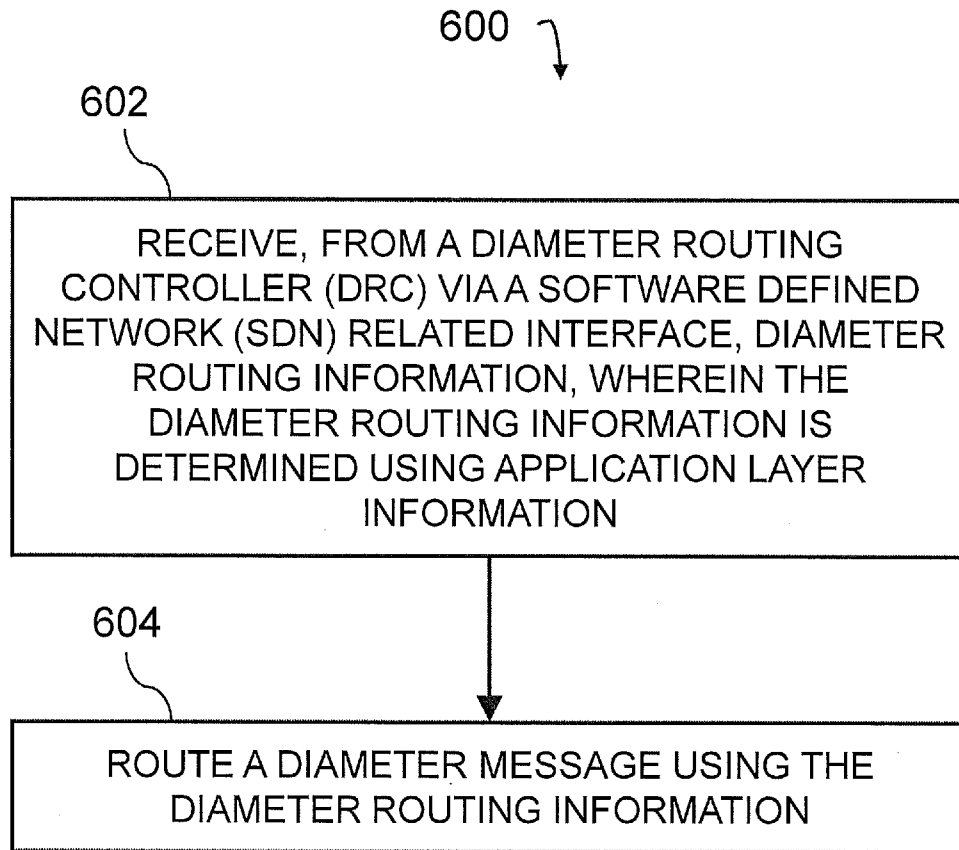


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2014/066240

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04L12/717 H04W40/02 H04L12/725
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04L H04W

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	<p>US 2009/232011 A1 (LI JIJUN [CN] ET AL) 17 September 2009 (2009-09-17) paragraph [0014] - paragraph [0024] paragraph [0067] - paragraph [0070] ----- -/--</p>	1-18



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

26 February 2015

Date of mailing of the international search report

05/03/2015

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
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Authorized officer

Ciurel, Cristian

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2014/066240

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	<p>"SPARC ICT-258457 Split Architecture for Large Scale Wide Area Networks. Deliverable D3.3",</p> <p>1 December 2011 (2011-12-01), XP055139597, Retrieved from the Internet: URL:http://www.fp7-sparc.eu/assets/deliverables/SPARC_D3.3_Split_Architecture_for_Large_Scale_Wide_Area_Networks.pdf [retrieved on 2014-09-11] paragraph [4.2.4NetworkmanagementforSDN] paragraph [5.5.2SPARCExtensiontotheTopologyDiscovery]</p>	1-18
A	<p>-----</p> <p>US 2013/250770 A1 (ZOU TING [US] ET AL) 26 September 2013 (2013-09-26) paragraph [0020] - paragraph [0041]</p> <p>-----</p>	1-18
A	<p>US 2011/202676 A1 (CRAIG JEFFREY ALAN [US] ET AL) 18 August 2011 (2011-08-18) paragraph [0040] - paragraph [0065]</p> <p>-----</p>	1-18

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2014/066240

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