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**Parker**

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(54) **SELECTION OF VIRTUAL NETWORK ELEMENTS**


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***H04L 12/801*** (2013.01)

(52) **U.S. Cl.**
CPC .................................... ***H04L 47/10*** (2013.01)

(58) **Field of Classification Search**
CPC ........ H04L 47/10; H04L 47/14; H04L 47/125
USPC ................................. 370/235, 236, 232, 230
See application file for complete search history.


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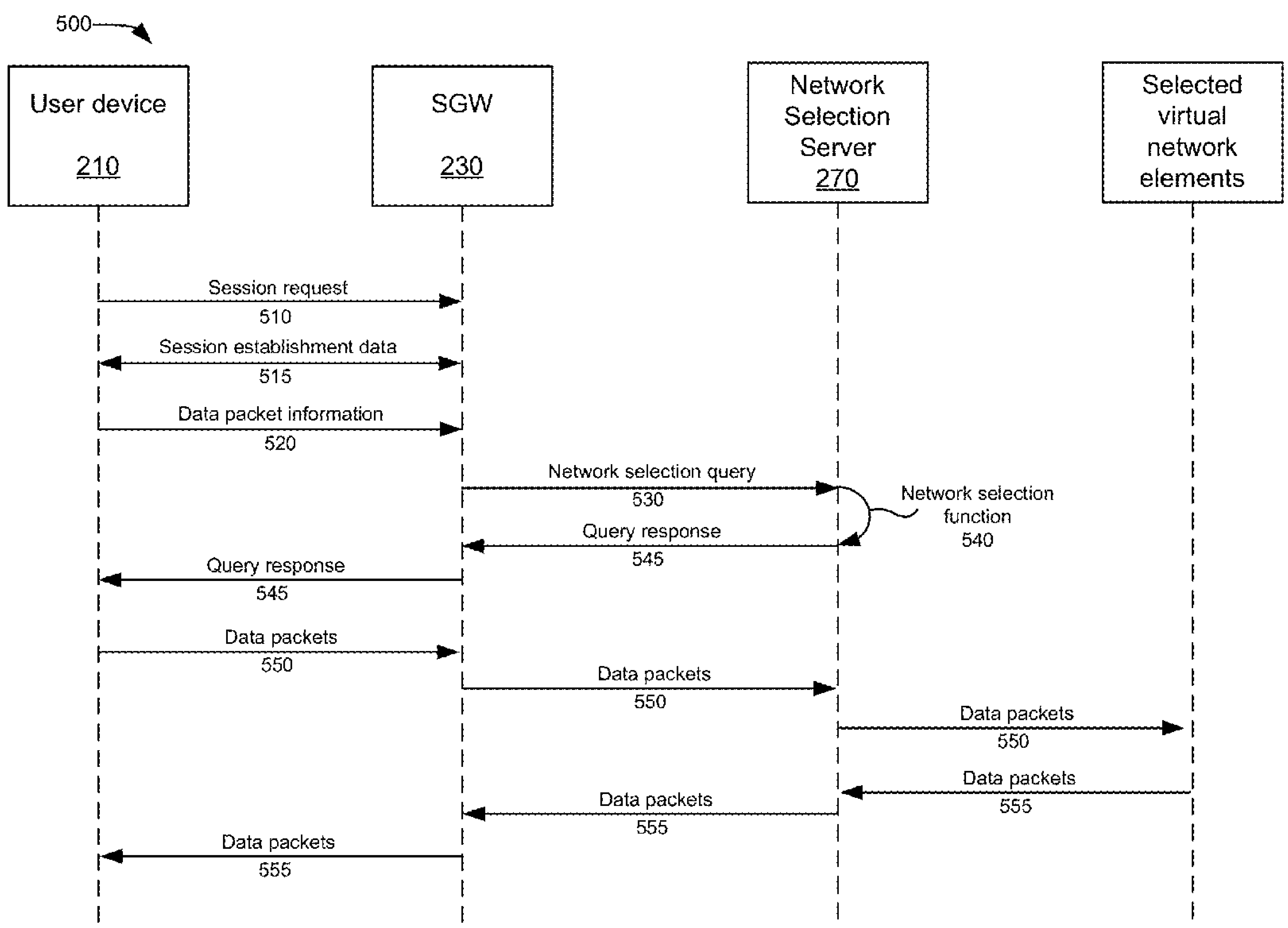
(57) **ABSTRACT**


A server may be configured to: receive a network selection query, associated with a user device. The network selection query may include information relating to a geographic location of the user device. The server may also select, based on information included in the network selection query, a virtual network element that services the geographic location of the user device and functions as a physical network element of an evolved packet core (EPC) network or an internet protocol (IP) multimedia subsystem (IMS) network. The server may also enable use of the selected virtual network element by the user device; receive a data packet destined for the selected virtual network element; provide the data packet to the selected virtual network element; and prevent the data packet from being sent to a non-selected virtual network element.


**20 Claims, 5 Drawing Sheets**



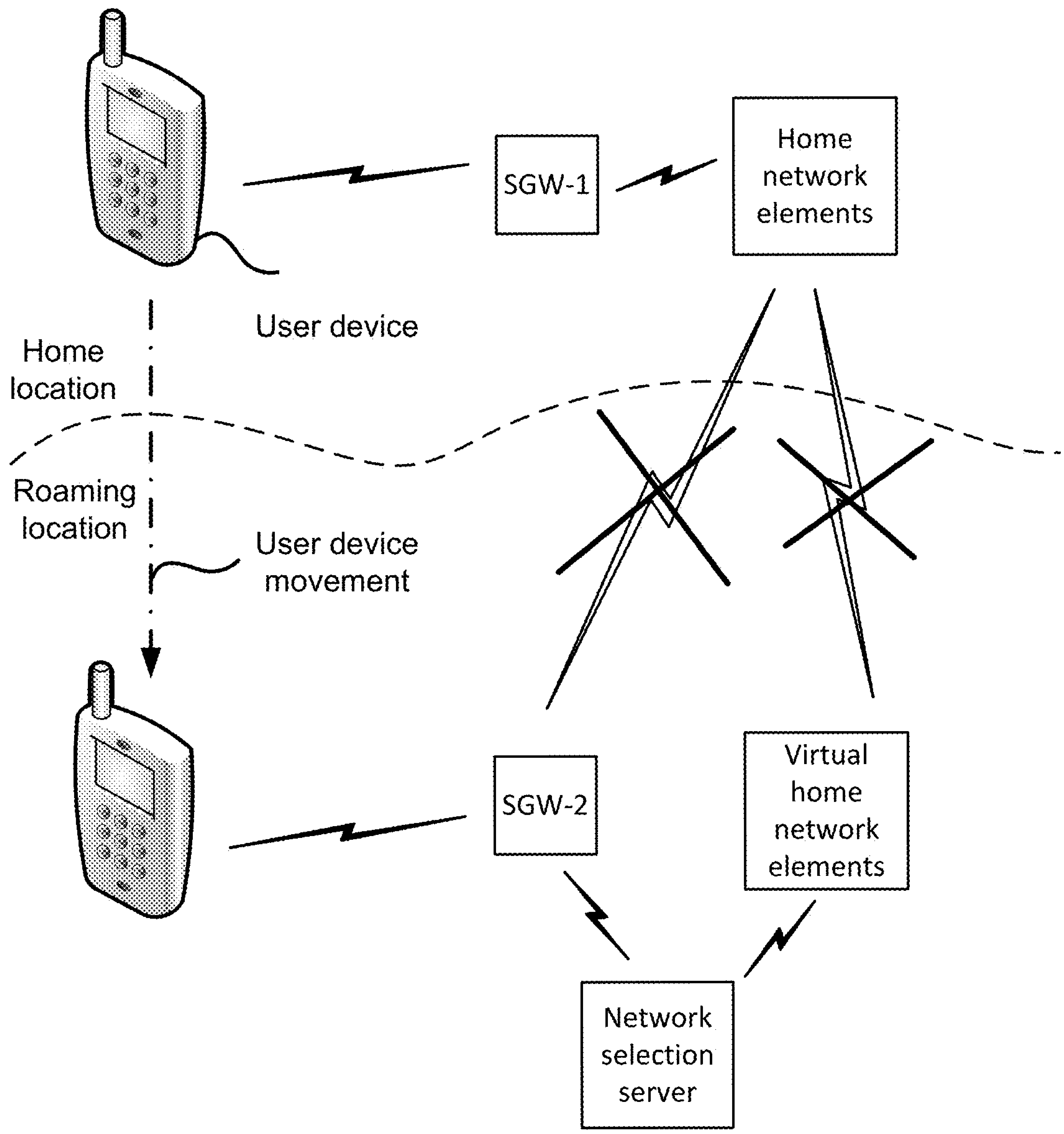
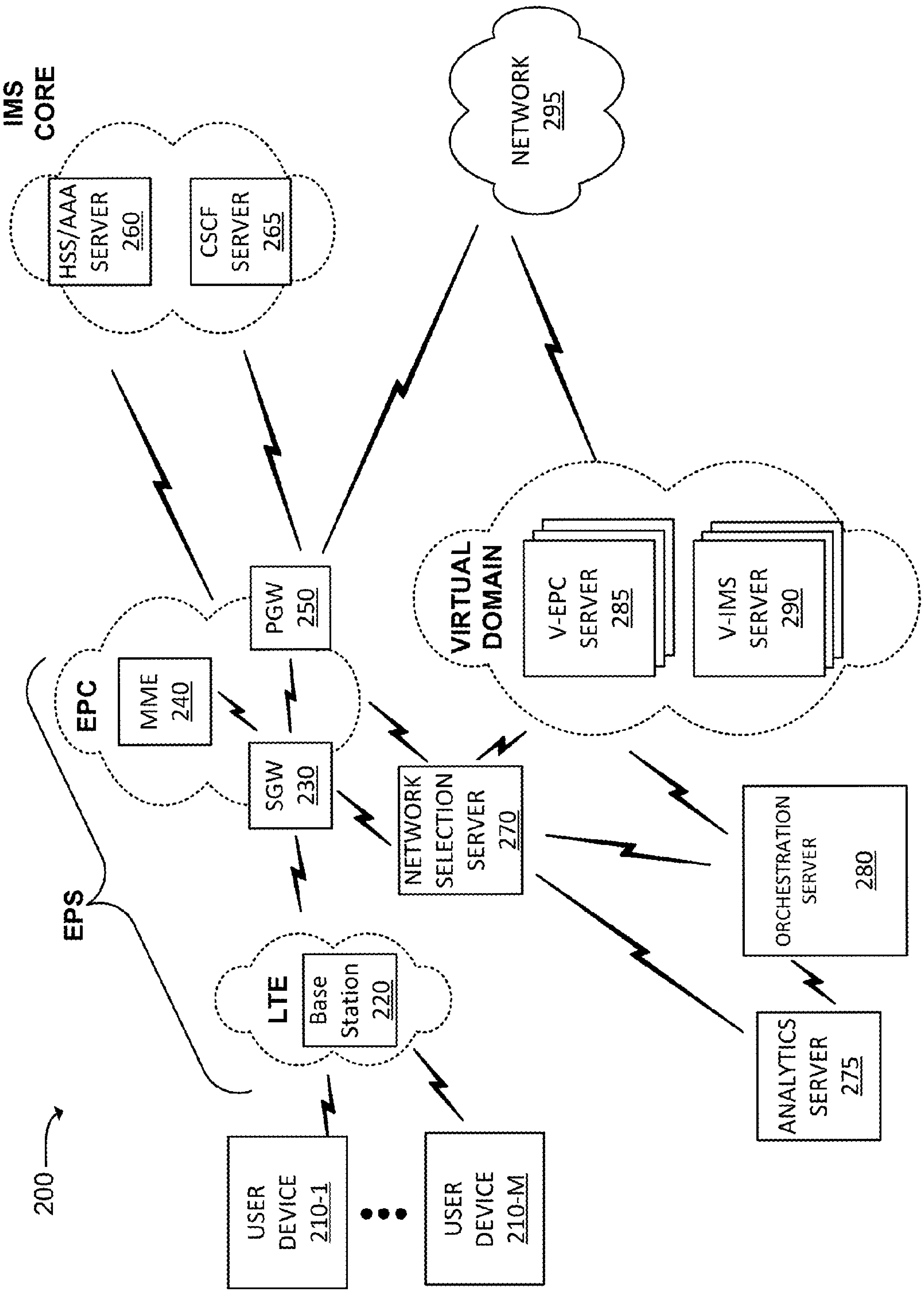

SGW-1
Home network elements
User device
Home location
Roaming location
User device movement
SGW-2
Virtual home network elements
Network selection server

Fig. 1



200
USER DEVICE 210-1
USER DEVICE 210-M
LTE
Base Station 220
EPS
EPC
SGW 230
MME 240
PGW 250
IMS CORE
HSS/AAA SERVER 260
CSCF SERVER 265
NETWORK SELECTION SERVER 270
ANALYTICS SERVER 275
ORCHESTRATION SERVER 280
VIRTUAL DOMAIN
V-EPC SERVER 285
V-IMS SERVER 290
NETWORK 295


Fig. 2

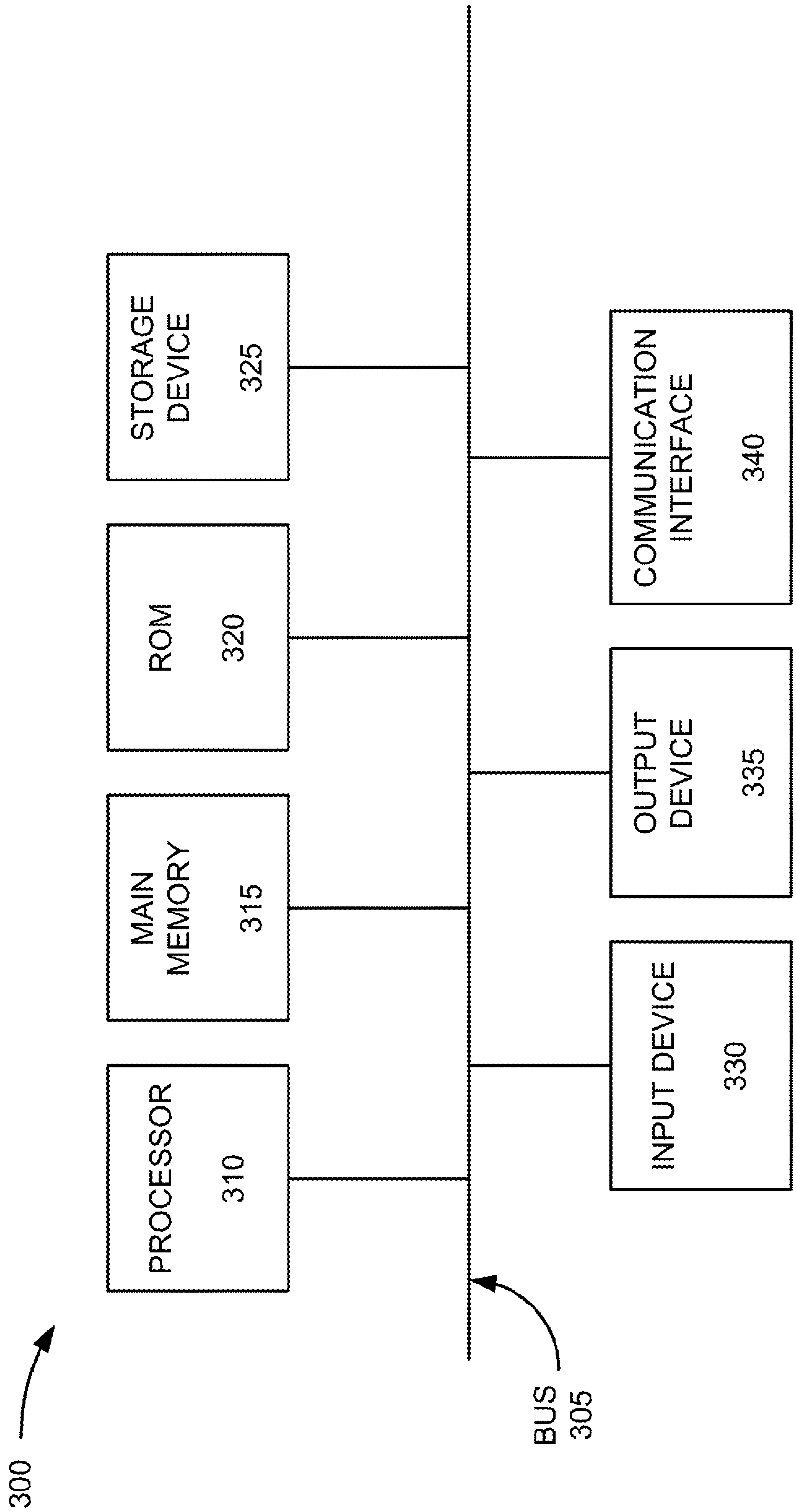

300
PROCESSOR 310
MAIN MEMORY 315
ROM 320
STORAGE DEVICE 325
BUS 305
INPUT DEVICE 330
OUTPUT DEVICE 335
COMMUNICATION INTERFACE 340

Fig. 3

400

410 420 430

| Network element information | | | Service area | | Element activity | |
|---|---|---|---|---|---|---|
| Element ID | Server ID | Virtual element type | Position | Radius | Bandwidth | Latency |
| 123 | V-EPC-1 | SGW | 51.507,-0.129 | 25 km | 100 mbps / <150 mbps | 200 ms / <100 ms |
| 456 | V-EPC-2 | PGW | 51.526,-0.238 | 20 km | 205 mbps / <200 mbps | 150 ms / <200 ms |
| 789 | V-EPC-2 | MME | 51.579,-0.110 | 40 km | 90 mbps / <100 mbps | 40 ms / <120 ms |
| 012 | V-IMS-1 | CSCF | 51.580,0.113 | 30 km | 95 mbps / <120 mbps | 75 ms / <100 ms |

Fig. 4

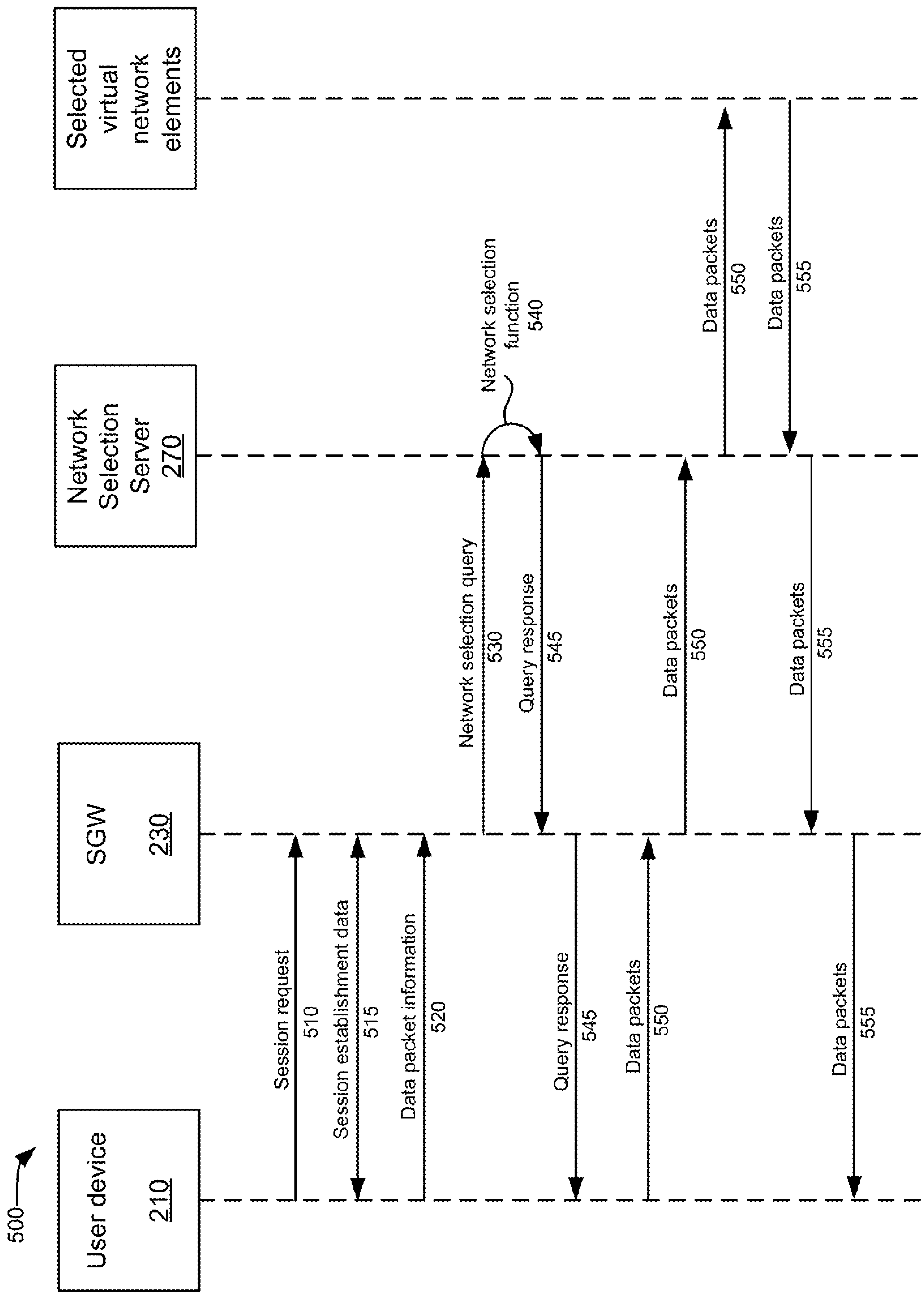

500
User device
210
SGW
230
Network Selection Server
270
Selected virtual network elements
Session request
510
Session establishment data
515
Data packet information
520
Network selection query
530
Network selection function
540
Query response
545
Query response
545
Data packets
550
Data packets
550
Data packets
550
Data packets
555
Data packets
555
Data packets
555

**Fig. 5**

# SELECTION OF VIRTUAL NETWORK ELEMENTS

## BACKGROUND

A user device may connect with a network element to allow a user to perform a task via the user device (e.g., browse the web, send and/or receive e-mail, etc.). Data flow, associated with performing tasks via the user device, may be cumbersome and redundant when the user device relocates to another geographic location and changes network element connections.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an example overview of an implementation described herein;

FIG. **2** illustrates an example environment in which systems and/or methods, described herein, may be implemented;

FIG. **3** illustrates example components of a device that may be used within the environment of FIG. **2**;

FIG. **4** illustrates an example data structure that may be stored by a server shown in FIG. **2**; and

FIG. **5** illustrates a call flow diagram of example operations capable of being performed by an example portion of the environment of FIG. **2**.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following detailed description refers to the accompanying drawings. The same reference numbers in different drawings may identify the same or similar elements.

Systems and/or methods, as described herein, may connect a user device that relocates from a "home" network (e.g., a network with which the user device is subscribed) to a "roaming" network (e.g., a network that the user device may not be subscribed to but may use to send and/or receive data) to virtual network elements that function as physical network elements (e.g., network devices in an evolved packet core (EPC), network devices in an internet protocol (IP) multimedia subsystem (IMS) network, etc.) associated with the home network of the user device. For example, a virtual network element may include a software image stored on a server to allow the server to function as a physical network element, such as physical network device used to transfer data packets in the context of allowing a user device to perform a task. In some implementations, the server storing the software image associated with the virtual network element may be stored by a data center in a geographic location associated with the roaming network.

FIG. **1** illustrates an example overview of an implementation described herein. As shown in FIG. **1**, assume that a user device is located in a first geographic location (e.g., a "home" location) and that the user device connects with a first serving gateway (e.g., SGW-**1**) that is part of a home network. In some implementations, SGW-**1** may connect with one or more network elements (e.g., "home" network elements which service the home network) to allow the user device to perform some task. For example, SGW-**1** may connect with home network elements to allow the user device to perform a task, such as send and/or receive e-mail, download a computer file (e.g., a video file, an audio file, a text document file, or some other file), browse the web, and/or perform some other function.

As further shown in FIG. **1**, assume that the user device relocates to a second geographic location (e.g., a "roaming" location) and that the user device connects with a second SGW (e.g. SGW-**2**) that is associated with a roaming network. In some implementations, SGW-**2** may connect with a network selection server (e.g., by resolving to an internet protocol (IP) address that is advertised by the network selection server) that may identify virtual network elements with which to connect. The network selection server may direct SGW-**2** to route data, associate with the user device, to one or more virtual network elements (e.g., "virtual home" network elements which service the "roaming" location and function as physical network elements associated with the home location) to allow the user device to perform some task. By redirecting SGW-**2** to the virtual home network elements (instead of the home network elements), the network selection server may reduce delays in servicing the roaming user device. As a result, the user device, via SGW-**2**, may connect with virtual network elements that function as home network elements and that service a geographic location in which the user device is currently located and/or have network capacity to satisfy a resource demand associated with an application of the user device.

In some implementations, an orchestration server may be used to add, delete, or modify virtual network elements in lieu of adding, deleting, or modifying physical network elements, thereby saving costs associated with adding, deleting, or modifying physical network elements.

FIG. **2** is a diagram of an example environment **200** in which systems and/or methods described herein may be implemented. As shown in FIG. **2**, environment **200** may include user devices **210** . . . **210**-M (where $M \geq 1$), a base station **220**, a serving gateway **230** (referred to as "SGW **230**"), a mobility management entity device **240** (referred to as "MME **240**"), a packet data network (PDN) gateway (PGW) **250**, a home subscriber server (HSS)/authentication, authorization, accounting (AAA) server **260** (referred to as an "HSS/AAA server **260**"), a call service control function (CSCF) server **265** (referred to as "CSCF server **265**"), network selection server **270**, analytics server **275**, orchestration server **280**, virtual evolved packet core EPC (V-EPC) server **285**, virtual Internet protocol (IP) multimedia subsystem IMS (V-IMS) server **290**, and a network **295**.

Environment **200** may include an evolved packet system (EPS) that includes a long term evolution (LTE) network and/or an EPC that operate based on a third generation partnership project (3GPP) wireless communication standard. The LTE network may be a radio access network (RAN) that includes one or more base stations, such as eNodeBs (eNBs), via which user device **210** communicates with the EPC. As shown in FIG. **2**, the LTE network may include base station **220**. The EPC may include SGW **230**, MME **240**, and/or PGW **250** that enables user device **210** to communicate with network **295** and/or an IMS core. The IMS network may include HSS/AAA server **260** and/or CSCF server **265** and may manage authentication, connection initiation, account information, a user profile, etc. associated with user device **210**.

Environment **200** may also include a virtual domain including V-EPC server **285** and V-IMS server **290** which may function similarly to a physical EPC and a physical IMS network. In some implementations, servers associated with the virtual domain may be stored by a data center located in a geographic location associated with a roaming network to service user devices **210** located in geographic location associated with the roaming network.

User device **210** may include a device that is capable of communicating with base station **220** and a network (e.g., network **295**). For example, user device **210** may include a radiotelephone, a personal communications system (PCS) terminal (e.g., that may combine a cellular radiotelephone with data processing and data communications capabilities), a personal digital assistant (PDA) (e.g., that can include a radiotelephone, a pager, Internet/intranet access, etc.), a smart phone, a laptop computer, a tablet computer, a camera, a personal gaming system, or another type device that is capable of communicating with base station **220**.

Base station **220** may include one or more network elements that receive, process, and transmit traffic, such as audio, video, text, and/or other data, destined for and/or received from user device **210**. In some implementations, base station **220** may be an eNB device and may be part of the LTE network. Base station **220** may receive traffic from and/or send traffic to network **295** via SGW **230** and PGW **250**. Base station **220** may send traffic to and/or receive traffic from user device **210** via an air interface. One or more of base stations **220** may be associated with a RAN, such as the LTE network.

SGW **230** may include one or more network elements, such as a data processing and traffic transfer devices. For example, SGW **230** may include a gateway, a router, a modem, a switch, a firewall, a network interface card (NIC), a hub, a bridge, a proxy server, an optical add-drop multiplexer (OADM), or some other type of device that processes and/or transfers traffic. SGW **230** may, for example, aggregate traffic received from one or more base stations **220** and may send the aggregated traffic to network **295** via PGW **250**. In some implementations, SGW **230** may route and forward user data packets, may act as a mobility anchor for a user plane during inter-eNB handovers, and may act as an anchor for mobility between LTE and other 3GPP technologies. For idle state user device **210**, SGW **230** may terminate a downlink (DL) data path and may trigger paging when DL data arrives for user device **210**.

MME **240** may include one or more network elements that may perform operations associated with a handoff to and/or from the EPS. In some implementations, MME **240** may perform operations to register user device **210** with the EPS, to handoff user device **210** from the EPS to another network, to handoff a user device **210** from the other network to the EPS, and/or to perform other operations. MME **240** may perform policing operations for traffic destined for and/or received from user device **210**. MME **240** may authenticate user device **210** (e.g., via interaction with HSS/AAA server **260**).

PGW **250** may include one or more network elements, such as a data processing and/or traffic transfer devices. For example, PGW **250** may include a gateway, a router, a modem, a switch, a firewall, a NIC, a hub, a bridge, a proxy server, an OADM, or some other type of device that processes and transfers traffic. PGW **250** may, for example, provide connectivity of user device **210** to external packet data networks by being a traffic exit/entry point for user device **210**. PGW **250** may perform policy enforcement, packet filtering, charging support, lawful intercept, and/or packet screening. PGW **250** may also act as an anchor for mobility between 3GPP and non-3GPP technologies.

HSS/AAA server **260** may include one or more network elements, such as a server device, that manages, updates, and/or stores, in a memory associated with HSS/AAA server **260**, profile information associated with user device **210**. The profile may include information that identifies applications and/or services that are permitted for and/or accessible by user device **210**, information associated with bandwidth or data rate thresholds associated with the applications or services, information associated with a user of user device **210** (e.g., a username, a password, a personal identification number (PIN), etc.), rate information, minutes allowed, and/or other information. Additionally, or alternatively, HSS/AAA server **260** may include a device that performs authentication, authorization, and/or accounting (AAA) operations for a communication session associated with user device **210**.

CSCF server **265** may include one or more network elements, such as a server device, that processes and routes calls to and from user device **210** via the EPC. For example, CSCF server **265** may process calls, received from network **295**, that are destined for user device **210**. In another example, CSCF server **260** may process calls, received from user device **210**, that are destined for network **295**.

Network selection server **270** may include a computing device, such as a server device, or a collection of server devices. In some implementations, network selection server **270** may select virtual network elements with which user device **210** may connect to transfer data packets to and from user device **210** and/or network **295**. For example, network selection server **270** may select a virtual network element of V-EPC server **285** or V-IMS server **290**, such as a virtual SGW element, a virtual PGW element, etc. In some implementations, network selection server **270** may select virtual network elements based on load-balancing techniques (e.g., based on network activity information), affinity thresholds, round-robin selection techniques, resource demand of a selected application of user device **210**, geographic location of a network query, and/or based on some other factor. In some implementations, network selection server **270** may broadcast an IP address to SGW **230** such that SGW **230** may detect and connect with network selection server **270**.

In some implementations, network selection server **270** may receive data packets from user device **210** (e.g., via SGW **230**) and provide the data packets to selected virtual network elements. Additionally, or alternatively, network selection server **270** may direct SGW **230** to provide data packets to the selected virtual network elements. In some implementations, network selection server **270** may determine analytics data relating to network activity data associated with a network element and may determine overloaded or under-loaded virtual network elements based on the analytics data. Additionally, or alternatively, network selection server **270** may provide the analytics data to analytics server **275**. In some implementations, network selection server **270** may function as an authoritative domain name system (DNS) server and/or a caching DNS server.

Analytics server **275** may include a network device, such as a server device, or a collection of server devices. In some implementations, analytics server **275** may receive performance data and thresholds associated with the performance data, from network selection server **270**. For example, analytics server **275** may receive analytics data (e.g., data relating to data rates or data throughput), and a threshold value associated with the analytics data associated with a virtual network element of V-EPC server **285** or V-IMS server **290** (e.g., a virtual SGW element, a virtual PGW element, etc.) or a physical network element (e.g., SGW **230**, MME **240**, and/or PGW **250**).

In some implementations, analytics server **275** may identify instances in which the received performance data does not satisfy the threshold value of the performance indicator for the virtual network element. For example, analytics server **275** may identify that the performance data, for a particular performance indicator (e.g., data rate), does not satisfy a threshold value associated with the performance indicator. For example, assume that analytics server **275** receives performance data relating to a data rate of 110 gigabits per second (Gbps). Further, assume that analytics server **275** stores a threshold of greater than 100 Gbps for the data rate performance indicator. In this example, analytics server **275** may determine that the performance data (e.g., 110 Gbps) satisfies the threshold (e.g., greater than 100 Gbps).

In some implementations, analytics server **275** may send instructions to orchestration server **280** to add, remove, combine, or migrate virtual virtual network elements from V-EPC server **285** and/or V-IMS server **290** such that the threshold for the performance indicator is satisfied.

Orchestration server **280** may include a network element, such as a server device or a collection of server devices. In some implementations, orchestration server **280** may store data associated with the topology of V-EPC server **285** and/or V-IMS server **290**. For example, orchestration server **280** may store information for a virtual network element (or multiple virtual network elements) associated with V-EPC server **285** and/or V-IMS server **290**, such as the type of service and/or function provided by the virtual network element, a virtual IP address associated with the virtual network element, and/or some other information regarding a virtual network element or group of virtual network elements. Orchestration server **280** may also receive an instruction from analytics server **275** to add, remove, or combine virtual network elements based on performance data associated with the virtual network elements. Further, orchestration server **280** may execute the instruction to add, remove, or combine virtual network elements based on receiving the instruction.

V-EPC server **285** may include a network element, such as a server device or a collection of server devices. In some implementations, V-EPC server **285** may store a virtual network element (e.g., in the form of a virtual image file) to allow V-EPC server **285** to function as a physical network element associated with the EPC (e.g., a PGW **250**, an SGW **230**, an MME **240**, and/or some other network element associated with the EPC). In some implementations, V-EPC server **285** may store multiple virtual network elements in a virtual container that services a particular geographic location. For example, V-EPC server **285** may store a first virtual container including virtual network elements that service a first geographic location and a second virtual container including virtual network elements that service a second geographic location. In some implementations, V-EPC server **285** may also include a virtual content delivery network and/or a virtual session delivery network.

V-IMS server **290** may include a network element, such as a server device or a collection of server devices. In some implementations, V-IMS server **290** may store a virtual network element (e.g., in the form of a virtual image file) to allow V-IMS server **290** to function as a physical network element associated with the IMS network (e.g., an HSS/AAA server, a CSCF server, and/or some other network element associated with the IMS network). In some implementations, V-IMS server **290** may store multiple virtual network elements in a virtual container that services a particular geographic location. For example, V-IMS server **290** may store a first virtual container including virtual network elements that service a first geographic location and a second virtual container including virtual network elements that service a second geographic location.

While virtual network elements associated with the EPC are described as being stored by V-EPC server **285** and virtual network elements associated with the IMS network are described as being stored by V-IMS server **290**, in practice, virtual network elements associated with the EPC and with the IMS network may be stored by a single server. Further, V-EPC server **285** and/or V-IMS server **290** may include additional virtual network elements, such as a virtual DNS server, a virtual tunnel gateway (TTG), a virtual policy and charging rule function (PCRF), and/or a virtual firewall. In some implementations, V-EPC server **285** and/or V-IMS server **290** may include virtual network elements that may be capable of functioning as a group of physical virtual network elements associated with different geographic locations.

Network **295** may include one or more wired and/or wireless networks. For example, network **295** may include a cellular network, a public land mobile network (PLMN), a second generation (2G) network, a third generation (3G) network, a fourth generation (4G) network, a fifth generation (5G) network, and/or another network. Additionally, or alternatively, network **295** may include a wide area network (WAN), a metropolitan area network (MAN), a telephone network (e.g., the Public Switched Telephone Network (PSTN)), an ad hoc network, an intranet, the Internet, a fiber optic-based network, and/or a combination of these or other types of networks.

The quantity of devices, network elements, and/or networks, illustrated in FIG. **2**, is not limited to what is shown. In practice, there may be additional devices, network elements, and/or networks; fewer devices and/or networks; different devices and/or networks; or differently arranged devices and/or networks than illustrated in FIG. **2**. Also, in some implementations, one or more of the devices of environment **200** may perform one or more functions described as being performed by another one or more of the devices of environment **200**. Devices of environment **200** may interconnect via wired connections, wireless connections, or a combination of wired and wireless connections.

FIG. **3** illustrates example components of a device **300** that may be used within environment **200** of FIG. **2**. Device **300** may correspond to user device **210**, base station **220**, SGW **230**, MME **240**, PGW **250**, HSS/AAA server **260**, CSCF **265**, network selection server **270**, analytics server **275**, orchestration server **280**, V-EPC server **285**, and/or V-IMS server **290**. Each of user device **210**, base station **220**, SGW **230**, MME **240**, PGW **250**, HSS/AAA server **260**, CSCF **265**, network selection server **270**, analytics server **275**, orchestration server **280**, V-EPC server **285**, and/or V-IMS server **290** may include one or more devices **300**, and/or one or more components of device **300**.

As shown in FIG. **3**, device **300** may include a bus **305**, a processor **310**, a main memory **315**, a read only memory (ROM) **320**, a storage device **325**, an input device **330**, an output device **335**, and a communication interface **340**. In some implementations, device **300** may include additional components, fewer components, different components, or differently arranged components.

Bus **305** may include a path that permits communication among the components of device **300**. Processor **310** may include a processor, a microprocessor, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or another type of processor that interprets and executes instructions. Main memory **315** may include a random access memory (RAM) or another type of dynamic storage device that stores information or instructions for execution by processor **310**. ROM **320** may include a ROM device or another type of static storage device that stores static information or instructions for use by processor **310**. Storage device **325** may include a magnetic storage medium, such as a hard disk drive, or a removable memory, such as a flash memory.

Input device **330** may include a mechanism that permits an operator to input information to device **300**, such as a control button, a keyboard, a keypad, or another type of input device. Output device **335** may include a mechanism that outputs information to the operator, such as a light emitting diode (LED), a display, or another type of output device. Communication interface **340** may include any transceiver-like mechanism that enables device **300** to communicate with other devices or networks. In some implementations, communication interface **340** may include a wireless interface, a wired interface, or a combination of a wireless interface and a wired interface.

Device **300** may perform certain operations, as described in detail below. Device **300** may perform these operations in response to processor **310** executing software instructions contained in a computer-readable medium, such as main memory **315**. A computer-readable medium may be defined as a non-transitory memory device. A memory device may include space within a single physical storage device or spread across multiple physical storage devices.

The software instructions may be read into main memory **315** from another computer-readable medium, such as storage device **325**, or from another device via communication interface **340**. The software instructions contained in main memory **315** may direct processor **310** to perform processes that will be described later. Alternatively, hardwired circuitry may be used in place of or in combination with software instructions to implement processes described herein. Thus, implementations described herein are not limited to any specific combination of hardware circuitry and software.

FIG. **4** illustrates an example data structure **400** that may be stored by one or more network elements in environment **200**. In some implementations, data structure **400** may be stored in a memory of analytics server **275**. In some implementations, data structure **400** may be stored in a memory separate from, but accessible by analytics server **275**. In some implementations, data structure **400** may be stored by some other network elements in environment **200**, such as SGW **230**, MME **240**, PGW **250**, HSS/AAA server **260**, CSCF **265**, network selection server **270**, orchestration server **280**, V-EPC server **285**, and/or V-IMS server **290**.

A particular instance of data structure **400** may contain different information and/or fields than another instance of data structure **400**. In some implementations, data structure **400** may correspond to information associated with geographic service areas of virtual network elements and network activity of the virtual network elements. One instance of data structure **400** may store information regarding one network element in environment **200**, whereas another instance of data structure **400** may store information regarding another network element in environment **200**. In some implementations, network selection server **270** may select a network element based on information stored by data structure **400**.

As shown in FIG. **4**, data structure **400** may include virtual network element information field **410**, service area field **420**, and element activity field **430**.

Virtual network element information field **410** may store information for virtual network elements included in environment **200**. For example, each entry of virtual network element information field **410** may store information that identifies a virtual network element. In some implementations, a virtual network element may be identified based on an element identifier (ID), a server ID, and a virtual element type. The server ID may store information that identifies a server that stores an image corresponding to the virtual network element (e.g., information that identifies a particular V-EPC server **285** or a particular V-IMS server **290**). In some implementations, network element information field **410** may include information that identifies a type of the virtual network element (e.g., a virtual PGW, a virtual SGW, etc.). For example, as shown in FIG. **4**, virtual network element information field **410** may store information to identify a virtual SGW having an element ID of 123 and being stored by a server (e.g., V-EPC server **285**) having the server ID of V-EPC-**1**.

Service area field **420** may store information that identifies a service area associated with the virtual network element identified in virtual network element information field **410**. For example, service area field **420** may store a center position and a radius corresponding to the service area of a virtual network element. As shown in FIG. **4**, service area field **420** may store the center position in the form of longitude and latitude coordinates and may store the radius in distance. For example, service area field **420** may store information to identify the longitude and latitude coordinates of “51.507, −0.129” and the radius 25 kilometers (km) for the virtual network element having the element ID of “123.” In some implementations, service area field **420** may store information that identifies a service area in another way, such as a state border, a province, a zip code, etc.

Element activity field **430** may store information that identifies network activity associated with virtual network elements. In some implementations, element activity field **430** may store network activity in terms of bandwidth, latency, jitter, or in some other form. In some implementations, element activity field **430** may store network activity for a virtual network element in real time or over a period of time. Additionally, element activity field **430** may store information that identifies threshold values in which the virtual network element may be considered to be overloaded. As an example, assume that the virtual network element having the element ID of “123,” is consuming 100 megabytes per second (mbps) of bandwidth and is associated with a threshold that indicates that the virtual network element is capable of handling less than 150 mbps of bandwidth. In this example, element activity field **430** may store information that identifies bandwidth activity (e.g., a real-time bandwidth activity or a bandwidth activity over a period of time) of 100 mbps. Further, element activity field **430** may store information that identifies a threshold value of less than 150 mbps.

Further, assume that the virtual network element having the element ID of “123” has a latency of 200 milliseconds (ms) and a threshold value of less than 100 ms that indicates that the virtual network element is overloaded when the latency of the virtual network element exceeds 100 ms. Further, assume that the virtual network element having the element ID of “123” has a jitter of 50 ms with a threshold value of less than 25 ms that indicates that the virtual network element is overloaded when the jitter of the virtual network element exceeds 25 ms. In some implementations, analytics server **275** may determine that the virtual network element having the ID of “123” may be overloaded since the latency activity value and the jitter activity value do not satisfy their respective threshold values.

In some implementations, analytics server **275** may direct orchestration server **280** to add virtual network elements (e.g., add virtual images representing virtual network elements to a server storing virtual network elements, such as V-EPC server **285** and/or V-IMS server **290**) based on determining an overloaded virtual network element. Additionally, or alternatively, analytics server **275** may direct orchestration server **280** to remove a virtual network element (e.g., delete a virtual image representing a virtual network element) based on identifying a substantially under-loaded virtual network element (e.g., when the network activity of a network element satisfies a threshold relating to when the network element is considered to be substantially under-loaded). Additionally, or alternatively, analytics server **275** may direct orchestration server **280** to combine the functions of multiple virtual network elements based on identifying multiple under-loaded virtual network elements.

While particular fields are shown in a particular format in data structure **400**, in practice, data structure **400** may include additional fields, fewer fields, different fields, or differently arranged fields than are shown in FIG. **4**.

In some implementations, network selection server **270** may advertise an IP address to SGW **230** such that SGW **230** may resolve to the IP address advertised by network selection server **270** (e.g., when user device **210** connects with SGW **230**). As described above, network selection server **270** may select virtual network elements with which user device **210** may connect (e.g., via SGW **230**), such as virtual network elements in the virtual domain. In some implementations, the virtual domain may include V-EPC server **285** and V-IMS server **290** which may each be provisioned to include one or more virtual images to function as physical network devices associated with a particular network (e.g., a network associated with a home network of user device **210**).

For example, V-EPC server **285** may include virtual images to function as SGWs **230**, MMEs **240**, or PGWs **250** associated with the home network. V-IMS server **290** may include virtual images to function as HSS/AAA servers **260** or CSCF servers **265**, associated with the home network, and may include information stored by physical HSS/AAA servers **260** or physical CSCF servers **265** (e.g., subscriber information of user device **210**, authorization information of user device **210**, etc.). In some implementations, orchestration server **280** may be used to add, modify, or delete virtual images stored by V-EPC server **285** and V-IMS server **290**.

In some implementations, the virtual domain may include multiple V-EPC servers **285** and multiple V-IMS servers **290** located in data centers associated with a geographical location of a roaming network which with user device **210** may connect when user device **210** relocates from a home network to the roaming network. As a result, user device **210** may connect with the virtual network elements (e.g., via SGW **230**) stored by servers located in the geographical location of the roaming network.

FIG. **5** illustrates a call flow diagram of example operations capable of being performed by an example portion **500** of environment **200**. As shown in FIG. **5**, portion **500** may include user device **210**, SGW **230**, network selection server **270**, and selected virtual network elements (e.g., virtual network elements selected by network selection server **270** for use by user device **210**). In some implementations, portion **500** may include components and/or perform functions described above in connection with, for example, one or more of FIGS. **1-3**. FIG. **5** may correspond to example operations that direct user device **210** to connect with virtual network elements that service a geographic location in which user device **210** is currently located and/or with virtual network elements that have capacity to satisfy a network demand of an application of user device **210**. For example, user device **210** may connect with virtual network elements via SGW **230** and/or via network selection server **270**.

In FIG. **5**, assume that user device **210** is located in a geographic location associated with a roaming network and that user device **210** connects with SGW **230** (e.g., via base station **220** that supports the roaming network). Further assume that user device **210** receives a selection of an application (e.g., a web browsing application, a messaging application, etc.). In some implementations, user device **210** may send session request **510** to SGW **230** (e.g., to access network **295** in order to allow user device **210** to send and/or receive data packets in the context of performing a function associated with the selected application). As shown in FIG. **5**, SGW **230** and user device **210** may exchange session establishment data **515** (e.g., authentication data or some other session establishment data) to establish a session.

As further shown in FIG. **5**, user device **210** may provide SGW **230** with data packet information **520** (e.g., data packets associated with performing a task via an application of user device **210**). For example, in the context of performing a web browsing task, data packet information **520** may include a request for data associated with a web page and/or a request for data associated with a computer file stored by a web server. Additionally, or alternatively, data packet information **520** may include some other data associated with performing some other task via an application of user device **210** (e.g., data relating to message sending and/or receiving functions, data relating to placing a voice over IP call, data relating to placing a video over IP call, etc.).

As further shown in FIG. **5**, SGW **230** may provide network selection server **270** with network selection query **530**. In some implementations, SGW **230** may determine a resource demand associated with data packet information **520** (e.g., a demand for a particular bandwidth, latency, and jitter), and may also determine a location associated with data packet information **520** (e.g., a network location or a geographic location in which data packet information **520** were received from user device **210** as determined by the location of SGW **230**). In some implementations, network selection query **530** may include the resource demand associated with data packet information **520**, the location associated with data packet information **520**, information for a task associated with data packet information **520** (e.g., a task to be performed by user device **210**, such as a task relating to message sending and/or receiving functions, placing a voice over IP call, placing a video over IP call, etc.), and/or some other information relating to data packet information **520** or user device **210**.

In some implementations, network selection server **270** may perform network selection function **540** based on receiving network selection query **530**. For example, network selection server **270** may determine virtual network elements that may receive data packet information **520** in the context of allowing user device **210** to perform a function via an application of user device **210**. In some implementations, network selection server **270** may select virtual network elements (e.g., virtual images stored by V-EPC server **285** or V-IMS server **290**) based on virtual network elements that service a location associated with a current location of user device **210** and/or a location associated with data packet information **520** (e.g., a network or geographic location of the particular SGW **230** that received data packet information **520** from user device **210**).

In some implementations, network selection server **270** may select virtual network elements based on a task to be performed by user device **210**. For example, network selection server **270** may select virtual network elements associated with V-EPC server **285** for tasks relating to a web browsing function or for some other task associated with the EPC. Additionally, or alternatively, network selection server **270** may select virtual network elements associated with V-IMS server **290** for tasks relating to message sending and/or receiving functions, tasks relating to placing or receiving telephone calls, or some other task associated with the IMS network.

In some implementations, network selection server **270** may make an initial selection of virtual network elements associated with V-EPC server **285** or V-IMS server **290** based on a type of task to be performed by user device **210**, as described above. Further, network selection server **270** may narrow the initial selection based on load-balancing techniques (e.g., by identifying virtual network elements having available network capacity to satisfy a resource demand associated with data packet information **520**). In some implementations, network selection server **270** may select virtual network elements in a manner that balances network load across multiple virtual network elements associated with multiple data centers. Additionally, or alternatively, network selection server **270** may select virtual network elements that satisfy a performance threshold (e.g., as determined by information stored by analytics server **275**).

Additionally, or alternatively, network selection server **270** may select virtual network elements based on some other technique (e.g., a round robin selection technique, selection of virtual network elements which are least loaded based on network activity information stored by data structure **400**). In some implementations, network selection server **270** may enable the selected virtual network elements for use by user device **210** based on performing network selection function **540**. In some implementations, network selection server **270** may select virtual network elements based on information stored by data structure **400** (e.g., service area information corresponding to a current location of user device **210** and/or using load-balancing techniques based on network element activity information corresponding to available network capacity to satisfy a resource demand associated with data packet information **520**).

As shown in FIG. **5**, network selection server **270** may provide query response **545** to SGW **230** including an indication that network selection server **270** has selected virtual network elements and/or enabled use of the selected virtual network elements. Additionally, query response **545** may include information for the selected virtual network elements with which user device **210** may communicate in order to send and/or receive data packets based on performing network selection function **540**. In some implementations, query response **545** may include information (e.g., an authentication script or some other authentication mechanism) to allow user device **210** to communicate with the selected virtual network elements (e.g., via SGW **230**) in order to send and/or receive data packets to and/or from the selected virtual network elements in order to perform a task via an application of user device **210**.

As shown in FIG. **5**, user device **210** may receive query response **545** to indicate that network selection server **270** has selected virtual network elements. In some implementations, user device **210** may provide data packets **550** to SGW **230** based on receiving query response **545**. Data packets **550** may include, for example, data relating to a communication (e.g., a call, a message, a web browsing instruction, etc.) to be routed by the selected virtual network elements (e.g., in the context of allowing user device **210** to perform a task via an application of user device **210**). In some implementations, network selection server **270** may receive data packets **550** (e.g., via SGW **230**) and may provide data packets **550** to the selected virtual network elements. Additionally, or alternatively, user device **210** may provide data packets **550** to the selected virtual network elements (e.g., via SGW **230**) without involving network selection server **270**. In some implementations, (e.g., when data packets are provided to the selected virtual network elements via network selection server **270**), network selection server **270** may prevent data packets **550** from being sent to virtual network elements that are not selected.

In some implementations, the selected virtual network elements may provide data packets **555** based on receiving data packets **550**. Data packets **555** may include, for example, data relating to a response of data packets **550** (e.g., data relating to a web page requested by user device **210** via data packets **550**, data relating to a computer file requested by user device **210** via data packets **550**, etc.). As shown in FIG. **5**, the selected virtual network elements may provide data packets **555** to user device **210** via network selection server **270** and/or SGW **230**. In some implementations, the selected virtual network elements may provide data packets **555** to user device **210** independently of network selection server **270**.

While a particular series of operations and/or data flows have been described above with regards to FIG. **5**, the order of the operations and/or data flows may be modified in other implementations. Further, non-dependent operations may be performed in parallel. Additionally, the operations and/or data flows are not limited to what is shown in FIG. **5**. For example, network selection server **270** may provide analytics information regarding virtual network elements to analytics server **275** such that analytics server **275** may store the analytics information in data structure **400**. Additionally, or alternatively, network selection server **270** may communicate with V-EPC server **285** and/or V-IMS server **290** to perform health checks on V-EPC server **285** and/or V-IMS server **290**.

As described above, user device **210**, via SGW **230**, may connect with virtual network elements (e.g., virtual EPC network elements and/or virtual IMS network elements) that service a geographic location in which the user device is currently located and/or with virtual network elements having network capacity to satisfy a resource demand associated with an application of the user device. In some implementations, orchestration server **280** may be used to add, delete, or modify virtual network elements in lieu of the expensive act of installing and/or modifying physical network elements. Additionally, or alternatively, physical network elements may be added, deleted, or modified in accordance with network resource demands associated with a particular geographic location.

The foregoing description provides illustration and description, but is not intended to be exhaustive or to limit the possible implementations to the precise form disclosed. Modifications and variations are possible in light of the above disclosure or may be acquired from practice of the implementations.

It will be apparent that different examples of the description provided above may be implemented in many different forms of software, firmware, and hardware in the implementations illustrated in the figures. The actual software code or specialized control hardware used to implement these examples is not limiting of the implementations. Thus, the operation and behavior of these examples were described without reference to the specific software code—it being understood that software and control hardware can be designed to implement these examples based on the description herein.

Even though particular combinations of features are recited in the claims and/or disclosed in the specification, these combinations are not intended to limit the disclosure of the possible implementations. In fact, many of these features may be combined in ways not specifically recited in the claims and/or disclosed in the specification. Although each dependent claim listed below may directly depend on only one other claim, the disclosure of the possible implementations includes each dependent claim in combination with every other claim in the claim set.

No element, act, or instruction used in the present application should be construed as critical or essential unless explicitly described as such. Also, as used herein, the article "a" is intended to include one or more items and may be used interchangeably with "one or more." Where only one item is intended, the term "one" or similar language is used. Further, the phrase "based on" is intended to mean "based, at least in part, on" unless explicitly stated otherwise.

What is claimed is:

1. A method comprising:

receiving, by one or more servers, a network selection query associated with a user device after the user device relocates from a home network to a roaming network,

the network selection query including information relating to a geographic location of the user device within the roaming network;

selecting, by the one or more servers and after receiving the network selection query, a plurality of virtual network elements based on a type of task to be performed by the user device,

the plurality of virtual network elements being located within the roaming network and functioning as physical network elements of the home network;

selecting, by the one or more servers and based on a particular technique, a virtual network element of the plurality of virtual network elements,

the home network including one of an evolved packet core (EPC) network or an internet protocol (IP) multimedia subsystem (IMS) network;

enabling, by the one or more servers, use of the virtual network element by the user device;

receiving, by the one or more servers and from the user device, a data packet destined for the virtual network element;

providing, by the one or more servers, the data packet to the virtual network element;

determining, by the one or more servers, that the virtual network element is overloaded based on one of a latency activity value or a jitter activity value associated with the virtual network element; and

directing, by the one or more servers, an addition of another virtual network element based on determining that the virtual net ark element is overloaded.

2. The method of claim 1, where the virtual network element includes at least one of:

a virtual mobility management entity (MME),

a virtual serving gateway (SGW),

a virtual packet data network (PDN) gateway (PGW),

a virtual domain name server (DNS),

a virtual tunnel termination gateway (TTG), or

a virtual firewall.

3. The method of claim 1, where the virtual network element includes at least one of:

a virtual policy and charging rule function (PCRF),

a virtual home subscriber server (HSS), or

a virtual call service control function (CSCF) server.

4. The method of claim 1, further comprising:

determining that a first virtual network element and a second virtual network element of the plurality of virtual network elements, are under-loaded; and

directing an orchestration server to combine functions the first virtual network element and the second virtual network element based on determining that the first virtual network element and the second virtual network element are under-loaded.

5. The method of claim 1, further comprising:

determining that the virtual network element is under-loaded; and

directing a removal of the virtual network element based on determining that the virtual network element is under-loaded.

6. The method of claim 1,

where the network selection query includes information relating to a network resource demand of an application of the user device,

where the method further comprises:

determining that the virtual network element includes capacity to satisfy the network resource demand, and

where selecting the virtual network element comprises:

selecting the virtual network element based on determining that the virtual network element includes capacity to satisfy the network resource demand.

7. The method of claim 1, further comprising:

determining that the virtual network element is performing in accordance with a performance parameter,

where selecting the virtual network element comprises:

selecting the virtual network element based on determining that the virtual network element is performing in accordance with the performance parameter.

8. The method of claim 1, further comprising:

receiving an identifier, associated with the user device, as part of the selection query,

where selecting the virtual network element comprises:

selecting the virtual network element further based on the identifier associated with the user device.

9. A system comprising:

one or more servers to:

receive a network selection query associated with a user device after the user device relocates from a home network to a roaming network,

the network selection query including information relating to a geographic location of the user device within the roaming network;

select a virtual network element based on the network selection query,

the virtual network element servicing the geographic location of the user device within the roaming network and functioning as a physical network element of the home network;

enable use of the virtual network element by the user device;

receive a data packet destined for the virtual network element;

provide the data packet to the virtual network element;

determine that the virtual network element is overloaded based on one of a latency activity value or a jitter activity value associated with the virtual network element; and

direct an addition of another virtual network element based on determining that the virtual network element is overloaded.

10. The system of claim 9, where the virtual network element includes at least one of:

a virtual mobility management entity (MME),

a virtual serving gateway (SGW),

a virtual packet data network (PDN) gateway (PGW),

a virtual domain name server (DNS),

a virtual tunnel termination gateway (TTG), or

a virtual firewall.

11. The system of claim 9, where the virtual network element includes one or more of:

a virtual policy and charging rule function (PCRF),

a virtual home subscriber server (HSS), or

a virtual call service control function (CSCF) server.

12. The system of claim 9, where, when directing the addition of the virtual network element, an analytics server, of the one or more servers, is to:

direct an orchestration server to add a virtual image, representing another virtual network element, to another server that stores the virtual network element based on determining that the virtual network element is overloaded.

**13**. The system of claim **12**, where the analytics server is further to:

determine that the other virtual network element is under-loaded; and

direct the orchestration server to delete the virtual image to remove the other virtual network element based on determining that the other virtual network element is under-loaded.

**14**. The system of claim **9**,

where the one or more servers are further to:

determine that the virtual network element is performing in accordance with a performance parameter, and

where, when selecting the virtual network element, the one or more servers are to:

select the virtual network element further based on determining that the virtual network element is performing in accordance with the performance parameter.

**15**. The system of claim **9**, where the one or more servers are further to:

receive an identifier, associated with the user device, as part of the network selection query,

where, when selecting the virtual network element, the one or more servers are to:

select the virtual network element further based on the identifier associated with the user device.

**16**. A non-transitory computer-readable medium for storing instructions, the instructions comprising:

a plurality of instructions which, when executed by one or more processors, cause the one or more processors to:

receive a network selection query associated with a user device after the user device relocates from a home network to a roaming network,

the network selection query including information relating to a geographic location of the user device within the roaming network;

select a virtual network element based on the network selection query,

the virtual network element servicing the geographic location of the user device within the roaming network and functioning as a physical network element of the home network;

enable use of the virtual network element by the user device;

receive a data packet destined for the virtual network element;

provide the data packet to the virtual network element;

determine that the virtual network element is overloaded based on one of a latency activity value or a jitter activity value associated with the virtual network element; and

direct an addition of another virtual network element based on determining that the virtual network element is overloaded.

**17**. The non-transitory computer-readable medium of claim **16**, where the virtual network element includes at least one of:

a virtual mobility management entity (MME),
a virtual serving gateway (SGW),
a virtual packet data network (PDN) gateway (PGW),
a virtual domain name server (DNS),
a virtual tunnel termination gateway (TTG), or
a virtual firewall.

**18**. The non-transitory computer-readable medium of claim **16**, where the virtual network element includes one or more of:

a virtual policy and charging rule function (PCRF),
a virtual home subscriber server (HSS), or
a virtual call service control function (CSCF) server.

**19**. The non-transitory computer-readable medium of claim **16**, where the one or more instructions to direct the addition of the other virtual network element comprise:

one or more instructions which, when executed by the one or more processors, cause the one or more processors to:

direct an orchestration server to add the other virtual network element based on determining that the virtual network element is overloaded.

**20**. The non-transitory computer-readable medium of claim **16**,

where the network selection query includes information relating to a network resource demand of an application of the user device, and

where the plurality of instructions to select the virtual network element comprise:

one or more instructions which, when executed by the one or more processors, cause the one or more processors to:

determine that the network element includes capacity to satisfy the network resource demand; and

select the network element further based on determining that the network element includes capacity to satisfy the network resource demand.

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