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IMS slicing based on slice identifiers from HSS

Abstract

In a telecommunication network, network slices can be identified by slice identifiers used within a core network. The same slice identifiers can also be used by elements of an IP Multimedia Subsystem (IMS) to identify the network slices. For example, a Home Subscriber Server (HSS) can be provisioned with user data associated with a user equipment (UE), including a slice identifier of a network slice that the UE is assigned to use. The HSS can provide the slice identifier to an S-CSCF in the IMS when the UE registers with the IMS. The S-CSCF can share the slice identifier with other IMS elements, such as a P-CSCF and/or one or more application servers. Accordingly, the IMS elements can determine key performance indicators (KPIs) and perform other operations in association with usage of network slices by UEs, based on the same slice identifiers used within the core network.

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Background/Summary

RELATED APPLICATIONS (1) This U.S. Patent Application claims priority to U.S. Provisional Patent Application No. 63/238,702, entitled “IMS SLICING USING SLICE-ID FROM HSS,” filed on Aug. 30, 2021, the entirety of which is incorporated herein by reference.

BACKGROUND
(1) A user equipment (UE), such as a mobile phone, can connect to a telecommunication network to access voice call services, data services, messaging services, and/or other types of services. The telecommunication network can include an Internet Protocol (IP) Multimedia Subsystem (IMS) that can assist with providing such services to UEs.
(2) For example, UEs may connect to a core network of the telecommunication network, such as a fifth generation (5G) core network, for instance via a radio access network (RAN) or other type of access network. The core network may in turn connect the UEs to the IMS. The IMS can include elements that can set up and/or help implement communication sessions for UEs for voice calls, video calls, messaging, data transfers, and/or other services.
(3) Network resources associated with the telecommunication network can also be associated with different network slices. For example, network resources can be allocated among different network slices. Each network slice can thus be used as an independent virtual network, because each network slice may be associated with different network resources. Different network slices may accordingly be created for different sets of subscribers, different types of data, and/or other different uses.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The detailed description is set forth with reference to the accompanying figures. In the figures, the left-most digit(s) of a reference number identifies the figure in which the reference number first appears. The use of the same reference numbers in different figures indicates similar or identical items or features.
(2) FIG. **1** shows an example of a network environment in which a UE can connect to a telecommunication network.
(3) FIG. **2** shows an example of a sequence of messages that can be exchanged between elements of the IMS during an IMS registration process for the UE.
(4) FIG. **3** shows an example of a sequence of messages that can be exchanged between elements of the IMS after the IMS registration process for the UE.
(5) FIG. **4** shows an example system architecture for an IMS element that is configured to use slice identifiers to determine which network slices UEs connected to the IMS are using.
(6) FIG. **5** shows a flowchart of an example method by which a S-CSCF can provide a slice identifier associated with the UE to a P-CSCF and/or one or more application servers during an IMS registration process for the UE.
(7) FIG. **6** shows a flowchart of an example method by which the P-CSCF can, following the IMS registration process for the UE, insert the slice identifier associated with the UE into a message associated with the UE.
(8) FIG. **7** shows a flowchart of an example method by which an IMS element can determine KPIs and/or billing data associated with a network slice based on usage of the network slice by one or

more UEs.

DETAILED DESCRIPTION

Introduction

(9) A telecommunication network can include, or be linked to, an IMS that can set up and/or manage communication sessions for UEs. The IMS can include different types of Call Session Control Functions (CSCFs) that can be configured to perform various operations, such as registering UEs with the IMS and routing messages associated with the UEs. The IMS can also include application servers that can implement services for UEs, such as a telephony application server (TAS) that can provide voice call services for UEs.

(10) The telecommunication network can also include a core network, such as 5G core network. UEs can connect to the core network via RANs or other access networks. The core network can in turn connect the UEs to the IMS, such that the UEs can access services that are implemented in part via the IMS.

(11) Network slicing allows different network slices to be created within the telecommunication network. Each network slice can operate as an independent virtual end-to-end network. For instance, in some examples, different network resources can be allocated to each network slice. An element of the core network can create and/or manage network slices, for example by allocating network resources to different network slices. The different network slices may be associated with different use cases, services, or applications.

(12) As an example, a slice orchestrator or other element of the core network may create and/or manage different network slices for Enhanced Mobile Broadband (eMBB) applications, Massive Internet of Things (MIoT) applications, Ultra-Reliable Low Latency Communication (URLLC) applications, vehicle-to-everything (V2X) applications, and/or other types of applications. In some situations, different network slices can be created for different types of services, such as a first network slice for voice services and a second network slice for data services.

(13) As another example, a core network element may create and/or manage different network slices for different groups of subscribers. For instance, a distinct network slice can be created for customers of a mobile virtual network operator (MVNO), to keep traffic associated with those customers distinct from other traffic within the telecommunication network.

(14) Resources of the core network and/or RANs can be allocated to different network slices as described above. Accordingly, network resources in the core network and/or RANs that have been allocated with different network slices can be used in association with UEs that are assigned to those network slices.

(15) However, in many systems, the IMS may not have information indicating which network slices individual UEs have been assigned to use and/or are allowed to use. Accordingly, the IMS may implement services for UEs that are assigned to any network slice. This may lead to UEs using IMS services via network slices that are intended for other types of services and/or other groups of UEs.

(16) For example, a UE may be assigned by the core network to use a network slice that is associated with low latency traffic. However, if the IMS does not have information indicating that the UE is assigned to the low-latency network slice, the IMS may provide other types of services to the UE that may increase the overall latencies associated with that network slice.

(17) As another example, UEs associated with an MVNO may be assigned by the core network to use a network slice associated with the MVNO. However, if the IMS does not have information indicating which UEs are associated with which network slices, the IMS may implement services for UEs that have been incorrectly assigned to the MVNO network slice.

(18) The systems and methods described herein allow elements of the IMS to identify which network slices UEs are using, based on the same slice identifiers used to identify the network slices in the core network. Accordingly, the IMS elements can determine key performance metrics (KPIs), billing data, and/or other information associated with usage of network slices, based on the same

slice identifiers of those networks slices used in the core network. The IMS elements can also use the slice identifiers to verify that UEs are using appropriate network slices. For instance, some IMS elements can be reserved for use with certain network slices in the core network, and the IMS elements can accordingly use slice identifiers associated with UEs to verify that only UEs associated with those network slices are engaged in services via the IMS elements.

Example Environment

(19) FIG. **1** shows an example 100 of a network environment in which a UE **102** can connect to a telecommunication network to engage in communication sessions for voice calls, video calls, messaging, data transfers, and/or any other type of communication. In some examples the UE **102** can be a mobile phone, such as a smart phone or other cellular phone. In other examples, the UE **102** can be a personal digital assistant (PDA), a media player, a tablet computer, a gaming device, a smart watch, a hotspot, an Internet of Things (IoT) device, a personal computer (PC) such as a laptop, desktop, or workstation, or any other type of computing or communication device.

(20) The telecommunication network can include a core network **104** and an IMS **106**. The telecommunication network can also include, or be associated with, an access network **108** that the UE **102** can use to connect to the core network **104** and the IMS **106**. For example, the access network **108** can be a RAN that includes base stations or other access points to which the UE **102** can wirelessly connect, and which can link the UE **102** to the core network **104**. As another example, the UE **102** can connect to the Internet via a Wi-Fi® access point or other type of access point, and use the Internet connection to communicate with the core network **104**. The core network **104** can be linked to the IMS **106**, such that the UE **102** can connect to the IMS **106** via a connection that extends through the core network **104**. The IMS **106** can set up and/or manage communication sessions for UEs, such as communication sessions for voice calls, video calls, messaging, data transfers, and/or other types of services.

(21) The UE **102**, the core network **104**, the IMS **106**, the access network **108**, and/or other networks or elements associated with the telecommunication network can be compatible with one or more types of radio access technologies, wireless access technologies, protocols, and/or standards. For example, the UE **102**, the core network **104**, the IMS **106**, and/or the access network **108** can be compatible with fifth generation (5G) New Radio (NR) technology, Long-Term Evolution (LTE)/LTE Advanced technology, other fourth generation (4G) technology, High-Speed Data Packet Access (HSDPA)/Evolved High-Speed Packet Access (HSPA+) technology, Universal Mobile Telecommunications System (UMTS) technology, Code Division Multiple Access (CDMA) technology, Global System for Mobile Communications (GSM) technology, WiMax® technology, WiFi® technology, and/or any other previous or future generation of radio access technology or wireless access technology.

(22) The core network **104** can be a 5G core network that is based on 5G technology. In some examples, the access network **108** can also be based on 5G technology. For instance, the access network **108** can be a 5G access network that includes one or more 5G base stations knowns as gNBs. The core network **104** can have a service-based system architecture in which different types of network functions can operate alone and/or together to implement services in the core network **104**. The network functions of the core network **104** can include a Unified Data Management (UDM) **110**, as shown in FIG. **1**. The core network **104** can also include other types of network functions in addition to the UDM **110**, such as an Authentication Server Function (AUSF), Access and Mobility Management Function (AMF), Network Slice Selection Function (NSSF), Policy Control Function (PCF), Session Management Function (SMF), Unified Data Repository (UDR), User Plane Function (UPF), Application Function (AF), and/or other network functions. Network functions may be implemented in the core network **104** using dedicated hardware, as software on dedicated hardware, or as virtualized functions on servers, cloud computing devices, or other computing devices.

(23) Different network slices can be created in the telecommunication network, so that different

network slices can be used by UEs for different use cases, services, or applications. A network slice can be a virtual network that is associated with network resources in the core network **104**. In some examples, the network slice can also be associated with network resources in the access network **108** and/or the IMS **106**, such that the network slice can be an end-to-end virtual network. For example, shared and/or different resources, such as hardware resources, computing resources, radio resources, and/or other resources of the core network **104**, the access network **108**, and/or the IMS **106**, can be allocated to different network slices. Accordingly, relative to having distinct hardware and/or other network elements for different end-to-end networks, different virtual networks can be created on shared resources via different network slices.

(24) Individual network slices may, in some examples, be associated with service level agreements (SLAs), Quality of Service (QoS) levels or 5G QoS Identifier (5QI) values, or other service-based requirements or goals. For instance, an SLA for a network slice may define types of services to be associated with the network slice, target latency measurements for the network slice, target throughput measurements for the network slice, reliability goals for the network slice, security goals or levels for the network slice, and/or other goals or attributes of the network slice.

(25) As a non-limiting example, a first SLA for a first network slice may indicate that the first network slice is intended for eMBB services. Because eMBB services may often involve relatively large data transmissions, but be delay-tolerant, the first SLA may indicate a relatively high throughput goal for the first network slice, but also allow relatively high latencies on the first network slice. However, in this example, a second SLA for a second network slice may indicate that the second network slice is intended for URLLC services. URLLC services may prioritize low latency measurements and high reliability, and accordingly the second SLA may indicate a relatively low latency goal and a relatively high reliability goal for the second network slice.

(26) In some examples, different network slices may be created for different types or groups of users, such as users associated with different customers, different subscriber levels or tiers, or other categories. As an example, UEs associated with a particular company may be directed to use a private eMBB network slice that has been created for that company's users, while other UEs may be directed to use one or more other eMBB network slices that have been created for general eMBB traffic or for other groups of users. This arrangement may enhance security for the company, as UEs associated with the company may be directed to use the private eMBB network slice created specifically for that company's users, and other UEs may be directed to use one or more other eMBB network slices. Although the different eMBB network slices in this example may each be intended to be used with eMBB services, the different eMBB network slices may be associated with different SLAs that define different throughput goals or other different attributes.

(27) Each network slice can be identified using a corresponding slice identifier **112**. The slice identifier **112** for a network slice can be an identifier that is used in the core network **104** to identify the network slice, and/or that is assigned to the network slice by an element of the core network **104**. For example, the slice identifier **112** for the network slice can be Single Network Slice Selection Assistance Information (S-NSSAI) associated with the network slice. The S-NSSAI of a network slice may indicate a Slice/Service Type (SST) of the network slice. As an example, the SST of a network slice may indicate that the network slice is intended for eMBB services, URLLC services, MIoT services, voice services, data services, or other types or groups of services. The S-NSSAI may also indicate a Slice Differentiator (SD). For example, if the telecommunication network includes multiple network slices with an “eMBB” SST, each of those multiple eMBB network slices may be distinguished using a different SD value such that each network slice has a different S-NSSAI overall.

(28) As described further below, the slice identifier **112** that is used by the core network **104** to identify a particular network slice can also be provided to elements of the IMS **106**. Accordingly, elements of the IMS **106** can identify network slices using the same slice identifiers that are used by elements of the core network **104**.

(29) When UEs, such as UE **102**, access services through the IMS **106**, elements of the IMS **106** can identify which network slices the UEs are using, based on the same slice identifiers used to identify those network slices in the core network **104**. Accordingly, the elements of the IMS **106** can determine KPIs, billing data, and/or other types of information associated with usage of different network slices by UEs, based on the slice identifiers of those network slices.
(30) The elements of the IMS **106** can also, or alternately, use the slice identifiers of network slices to determine if UEs are accessing IMS services via appropriate network slices. For instance, if a UE is associated with a slice identifier for a network slice dedicated to voice calls, but the UE is attempting to access IMS services associated with high-speed data transfers, elements of the IMS **106** may deny access to those services because high-speed data transfers may create congestion on the voice call network slice and/or otherwise negatively impact performance of voice call services on the voice call network slice. The elements of the IMS **106** may instead initiate a re-registration or transfer procedure that causes the UE to be reassigned to a different network slice that is dedicated to high-speed data transfers.
(31) In some examples, portions of the infrastructure of the IMS **106**, such as particular groups of servers, can be reserved for use with particular network slices. Accordingly, elements of the IMS **106** can similarly use slice identifiers associated with UEs to determine which corresponding portions of the IMS infrastructure can serve the UEs, and/or verify that the UEs are using the portions of the IMS infrastructure that are associated with those slice identifiers.
(32) The elements of the IMS **106** can include Call Session Control Functions (CSCFs) that can operate to register the UE **102** with the IMS **106**, manage communication sessions associated with the UE **102**, and perform other functions as described further herein. The CSCFs of the IMS **106** can include a Proxy CSCF (P-CSCF) **114** and a Serving CSCF (S-CSCF) **116**, as shown in FIG. **1**. Although not shown in FIG. **1**, the CSCFs can also include an Interrogating CSCF (I-CSCF). The IMS **106** can include multiple instances of the P-CSCF **114**, the I-CSCF, and/or the S-CSCF **116**. In some examples one or more of the CSCFs may be known by other names, and/or be incorporated into the same or different network elements. For instance, the P-CSCF **114** can be incorporated into, or be referred to as, a Session Border Gateway (SBG), Session Border Controller (SBC), or another network element.
(33) The elements of the IMS **106** can also include one or more application servers **118** that provide services for UEs, such as services for voice calls, video calls, messaging, data transfers, and/or other types of communications or operations. For example, the application servers **118** can include a telephony application server (TAS) that provides or assists with telephony services, such as services for voice and/or video calls. Other types of application servers **118** may implement presence services, messaging services, and/or other types of services.
(34) Elements of the IMS **106** can exchange data with each other and/or the UE **102** using Session Initiation Protocol (SIP) messages. For example, as will be described further below, UEs may initiate a service by sending a SIP request to the IMS **106**, and the IMS **106** can return a corresponding SIP response to the UE **102**.
(35) Elements of the core network **104** and/or the IMS **106** can communicate with a Home Subscriber Server (HSS) **120**. The HSS **120** can include a database of user profile information associated with the UE **102** and other UEs. For example, the HSS **120** can store user profiles for subscribers, location information, and/or other information about users associated with UEs. The HSS **120** can also be involved in authentication and/or authorization of users and/or UEs in the IMS **106**. The HSS **120** can communicate with network elements using Diameter protocol interfaces or other types of connections. In some examples, the HSS **120** can be part of the IMS **106**. In other examples, the HSS **120** can be outside the IMS **106**.
(36) The UDM **110** in the core network **104** can be similar to the HSS **120**, and can store user profile information associated with the UE **102** and other UEs. For example, the UDM **110** can manage and/or store data for access authorization, user registration, user profiles, and/or other types

of user data that may be used within the core network **104**. In some examples, the UDM **110** may be linked to a UDR in the core network **104** that may store the same or similar types of user data. For example, the UDM **110** may provide user data to the UDR and/or determine what types of user data are stored at the UDR.

(37) The HSS **120** may accordingly be configured to store and/or provide user data in association with the IMS **106**, while the UDM **110** can be configured to store and/or provide the same or similar user data in association with the core network **104**. In some examples the HSS **120** may store and/or provide user data for an LTE core network, and can also store and/or provide the user data to elements of the IMS **106**. The UDM **110** can be a 5G counterpart to the HSS **120**, such that network functions and other elements of the core network **104** can receive user data from the UDM **110** instead of from the HSS **120**.

(38) The core network **104** can have a subscriber provisioning platform **122** that can provide user data to both the UDM **110** and the HSS **120**. Accordingly, the subscriber provisioning platform **122** can provide the same or similar user data to both the UDM **110** and the HSS **120**, such that elements of the core network **104** can access the user data from the UDM **110** and elements of the IMS **106** can access the user data from the HSS **120**. The subscriber provisioning platform **122** may be known by other names, and/or be incorporated into other network functions or network elements. For example, the subscriber provisioning platform **122** can be incorporated into, or be referred to as, a switch controller (SC), a subscriber management function, or another network function or network element.

(39) As described herein, user data associated with the UE **102**, provided by the subscriber provisioning platform **122** to both the UDM **110** and the HSS **120**, can include the slice identifier **112** that identifies a network slice associated with the UE **102**. For example, a set of network slices can be created in the telecommunication network, and each network slice can be associated with a distinct slice identifier. User data for subscribers of the telecommunication network can include slice identifiers of network slices that UEs, associated with the subscribers, are permitted to use. Accordingly, the subscriber provisioning platform **122** can provision both the UDM **110** and the HSS **120** with user data associated with the UE **102**, including the slice identifier **112** of a network slice that the UE **102** is permitted to use.

(40) In some examples, the subscriber provisioning platform **122** can include the slice identifier **12** associated with the UE **102** in a “service-info” field of Extensible Markup Language (XML) data provided to the HSS **120** during provisioning of user data associated with the UE **102**. The “service-info” field may in some examples be an existing field of the XML data that the subscriber provisioning platform **122** provides to the HSS **120**, but the “service-info” field may be otherwise unused or have space for additional data. Accordingly, providing the slice identifier **112** associated with the UE **102** in the “service-info” field can have minimal impact on the provisioning of the HSS **120** with user data. In other example, the subscriber provisioning platform **122** can include the slice identifier **112** associated with the UE **102** to the HSS **120** in a custom field of XML data, or any other field, data element, or type of message.

(41) Elements of the core network **104** can accordingly use the slice identifier **112** associated with the UE **102**, stored at the UDM **110**, to determine which network slice the UE **102** is using and/or is permitted to use. Similarly, elements of the IMS **106** can use the slice identifier **112** associated with the UE **102**, stored at the HSS **120**, to determine which network slice the UE **102** is using and/or is permitted to use. Accordingly, elements of the core network **104** and elements of the IMS **106** can use the same slice identifier **112** to identify the same network slice that the UE **102** is using and/or is permitted to use.

(42) Elements of the IMS **106** can receive the slice identifier **112** associated with the UE **102** during an IMS registration process for the UE **102**. For example, during the IMS registration process, the HSS **120** can provide the slice identifier **112** associated with the UE **102** to the S-CSCF **116**. The S-CSCF **116** can then provide the slice identifier **112** associated with the UE **102** to

the P-CSCF **114** and/or to one or more of the application servers **118**. The P-CSCF **114**, the S-CSCF **116**, and/or the application servers **118** can store the slice identifier **112** associated with the UE **102** in a cache or other data repository. In some examples, the application servers **118** can also, or alternately, obtain the slice identifier **112** associated with the UE **102** from the HSS **120** directly. For instance, an application server **118** can retrieve the slice identifier **112** from the HSS **120** if the application server **118** did not receive the slice identifier **112** from the S-CSCF **116** during the IMS registration process, or if the application server **118** is configured to use the slice identifier **112** received directly from the HSS **120** to verify the slice identifier **112** received from the S-CSCF **116** during the IMS registration process. Examples of elements of the IMS **106** receiving the slice identifier **112** during the IMS registration process is discussed further below with respect to FIG. **2** and FIG. **5**.

(43) After elements of the IMS **106** have received the slice identifier **112** associated with the UE **102**, the elements of the IMS **106** can use the slice identifier **112** to determine which network slice the UE **102** is using to exchange data with the IMS **106**. For example, when the P-CSCF **114** receives a SIP message from the UE **102**, the P-CSCF **114** can retrieve the slice identifier **112** associated with the UE **102** from a cache or other data repository maintained by the P-CSCF **114**. The P-CSCF **114** can insert the slice identifier **112** associated with the UE **102** into the SIP message, and then forward the SIP message on to the S-CSCF **116** and/or an application server **118**. Accordingly, the S-CSCF **116**, the application server **118**, and/or other elements of the IMS **106** can use the slice identifier **112** associated with the UE **102**, inserted into the SIP message by the P-CSCF **114**, to determine which network slice the UE **102** is using to communicate with the IMS **106**. In some examples, elements of the IMS **106** can similarly include or insert the slice identifier **112** associated with the UE **102** into SIP messages being exchanged between the elements of the IMS **106** and/or being sent back to the UE **102**. Examples of the slice identifier **112** associated with the UE **102** being inserted into SIP messages are discussed further below with respect to FIG. **3** and FIG. **6**.

(44) One or more elements of the IMS **106** can be configured to use the slice identifier **112** associated with the UE **102** to verify that the UE **102** is permitted to use services of the IMS **106** via the corresponding network slice. One or more elements of the IMS **106** can also be configured to use the slice identifier **112** associated with the UE **102** to determine KPIs, billing data, or other information associated with usage of the corresponding network slice.

(45) As an example, a TAS of the IMS **106** that implements voice call services may be configured to verify that the slice identifier **112** associated with the UE **102** indicates that the UE **102** is using a network slice that has been set up in the core network **104** for voice services. The TAS may determine the slice identifier **112** associated with the UE **102** based on the slice identifier being inserted into a SIP message by the P-CSCF **114**, from a cache of the TAS that stores the slice identifier **112** based on a previous IMS registration process, and/or by requesting the slice identifier **112** directly from the HSS **120**. The TAS may implement requested voice call services for the UE **102** if the slice identifier **112** associated with the UE **102** matches the slice identifier **112** used in the core network **104** for a network slice associated with voice call services. If the slice identifier **112** associated with the UE **102** does not match the slice identifier **112** used in the core network **104** for a network slice associated with voice call services, the TAS may deny the voice call services, and/or instruct the P-CSCF **114** or other network elements to initiate a re-registration procedure that can assign the UE **102** on the network slice associated with voice call services.

(46) As another example, if the P-CSCF **114** receives a SIP request from the UE **102**, the P-CSCF **114** can retrieve the slice identifier **112** associated with the UE **102** from a cache or other data store. The P-CSCF **114** can determine that the slice identifier **112** corresponds with a particular network slice, and can verify that the S-CSCF **116** and/or an application server **118** to which the SIP request will be forwarded are also associated with that particular network slice. If the S-CSCF **116** and/or the application server **118** are associated with a different network slice, for instance if the S-CSCF

116 and/or the application server **118** are reserved for use by UEs associated with a different network slice, the P-CSCF **114** may cause the UE **102** to re-register with the IMS **106** such that the UE **102** becomes re-assigned to different instances of the S-CSCF **116** and/or the application server **118** that are associated with the network slice that corresponds to the slice identifier **112**.

(47) As yet another example, the P-CSCF **114**, the S-CSCF **116**, and/or the application servers **118** can track usage of IMS services by the UE **102** and other UEs based on the slice identifiers associated with those UEs. For example, if the slice identifier **112** associated with the UE **102** corresponds with a particular network slice that has been set up in the core network, the P-CSCF **114**, the S-CSCF **116**, and/or the application servers **118** can use the slice identifier **112** to determine when the UE **102** uses that particular network slice to engage in services via the IMS **106**, track a number of times the UE **102** uses the particular network slice to engage in instances of the services, and/or otherwise track usage of the particular network slice by the UE **102**.

(48) The P-CSCF **114**, the S-CSCF **116**, and/or the application servers **118** can similarly use slice identifiers associated with different UEs to track usage of IMS services by the UEs via one or more network slices. Accordingly, the P-CSCF **114**, the S-CSCF **116**, and/or the application servers **118** can determine KPIs associated with network slices identified by corresponding slice identifiers, such as KPIs indicating how often particular network slices are used to engage in communication sessions or other IMS services, which types of communication sessions or other IMS services are being used via particular network slices, total numbers of instances of communication sessions or other IMS services that UEs are engaging in over periods of time, how usage of network slices for communication sessions or other IMS services compares to total capacities of the network slices, latency metrics associated with communication sessions or IMS services that UEs are engaging in via the network slices, throughput metrics associated with communication sessions or IMS services that UEs are engaging in via the network slices, and/or other types of KPIs.

(49) In some examples, an IMS element, such as the P-CSCF **114**, the S-CSCF **116**, or the application server **118**, can compare KPIs associated with particular network slices against corresponding SLAs for the network slices. For instance, if an SLA for a network slice indicates a particular latency goal for traffic associated with the network slice, the IMS element may compare latency KPIs determined for the network slice against the latency goal defined in the SLA to determine whether the traffic associated with the network slice in the IMS **106** is meeting the latency goal.

(50) The P-CSCF **114**, the S-CSCF **116**, and/or the application servers **118** can also use slice identifiers associated with UEs to determine billing data associated with usage of corresponding network slices. For example, a TAS may use slice identifiers associated with UEs to determine that, over a period of time, UEs have made 10,000 calls via a network slice that has been set up in the core network **104** to handle traffic associated with an MVNO. Accordingly, the TAS or another network element can determine billing data indicating that the MVNO should be charged an amount corresponding to 10,000 calls having been made via that network slice.

(51) In some examples, IMS elements, such as the P-CSCF **114**, the S-CSCF **116**, and/or the application servers **118**, may also be configured to prioritize operations associated with one or more network slices over one or more other network slices, based on corresponding slice identifiers. Accordingly, if a first UE is associated with a higher-priority network slice than a second UE, an IMS element may use slice identifiers associated with the first UE and the second UE to determine that the IMS should prioritize routing traffic and/or performing other operations associated with the first UE and the higher-priority network slice over routing traffic and/or performing other operations associated with the second UE and the lower-priority network slice.

(52) Additional examples of a network element associated with the IMS **106** using slice identifiers associated with UEs to identify the network slices being used by the UEs to access the IMS **106**, to determine KPIs and/or billing data associated with network slices, and/or for other operations are discussed further below with respect to FIG. **7**. Because the elements of the IMS **106** can use the

same slice identifier **112** to identify each network slices as elements of the core network **104**, information such as KPIs and/or billing data associated with particular network slices determined by elements of the IMS **106** can be used to determine and/or evaluate usage of those network slices in the core network **104**.

(53) FIG. **2** shows an example 200 of a sequence of messages that can be exchanged between elements of the IMS **106** during an IMS registration process for the UE **102**. The sequence of messages shown in FIG. **2** can provide the IMS elements, including the P-CSCF **114**, the S-CSCF **116**, and one or more application servers **118** with the slice identifier **112** associated with the UE **102**. As described above, the slice identifier **112** associated with the UE **102** can identify a corresponding network slice that the UE **102** is using and/or is allowed to use. The slice identifier **112** provided to the IMS elements during the IMS registration process as shown in FIG. **2** can also be the same as the slice identifier **112** used to identify the network slice within the core network **104**, such as an S-NSSAI.

(54) When the UE **102** attaches to the telecommunication network or otherwise initiates communication with the IMS **106**, an IMS registration process can occur. During the IMS registration process, the UE **102** can send a registration message **202** to the P-CSCF **114**. For example, the registration message **202** can be a SIP REGISTER message. The registration message **202** may indicate one or more identifiers of the UE **102**, such as a Mobile Station International Subscriber Directory Number (MSISDN), International Mobile Subscriber Identity (IMSI), and/or other identifiers. The P-CSCF **114** can forward the registration message **202** to the S-CSCF **116** as shown in FIG. **2**, for instance after an I-CSCF has assigned the UE **102** to the S-CSCF **116**.

(55) The S-CSCF **116** can serve as a registrar for the IMS **106**, and can authenticate the UE **102** and complete registration of the UE **102** with the IMS **106** in association with the HSS **120**. For example, the S-CSCF **116** can send a Server Assignment Request (SAR) **204** associated with the UE **102** to the HSS **120**. The SAR **204** can include one or more identifiers of the UE **102**, such as a MSISDN, IMSI, and/or identifiers. The SAR **204** can also request user data, such as subscriber information, associated with the identified UE **102**. The HSS **120**, having been provisioned by the subscriber provisioning platform **122** with the slice identifier **112** that is associated with the UE **102**, can return to the S-CSCF **116** a Server Assignment Answer (SAA) **206** that includes the slice identifier **112** associated with the UE **102**. The SAA **206** can also include other types of user data associated with the UE **102**. In some examples, the HSS **120** can include the slice identifier **112** associated with the UE **102** in a “service-info” field, custom field, or other field of XML data associated with the SAA **206**. In other examples, the HSS **120** can include the slice identifier **112** in any other field or data element of the SAA **206**.

(56) The S-CSCF **116** can include the slice identifier **112**, received from the HSS **120** in the SAA **206**, in a registration response **208** that the S-CSCF **116** sends to the P-CSCF **114**. In some examples, the registration response **208** can be a “200 OK” message that the S-CSCF **116** sends to the P-CSCF **114** after processing the registration message **202**, and the S-CSCF **116** can include the slice identifier **112** in a private header, or other data field, of the “200 OK” message. In other examples, S-CSCF **114** can send the slice identifier **112** to the P-CSCF **114** in a different type of message, such as a different type of registration response **208** or a separate message sent in addition to the registration response **208**. After receiving the slice identifier **112** associated with the UE **102** from the S-CSCF **116**, the P-CSCF **114** can cache the slice identifier **112** associated with the UE **102** for future use, for example as discussed further below with respect to FIG. **3**. For instance, the P-CSCF **114** can cache the slice identifier **112** included in the registration response **208** in a database, in association with the MSISDN, IMSI, and/or other identifiers of the UE **102**.

(57) In some examples, the S-CSCF **116** can also select one or more application servers **118** for the UE **102**, which can implement services for the UE **102** as described above. The S-CSCF **116** can provide the slice identifier **112** associated with the UE **102** to the selected application servers **118**. For example, the S-CSCF **116** can include the slice identifier **112** in a Third Party Registration

(TPR) message **210** that the S-CSCF **116** sends to a selected application server **118** in association with the UE **102**. In some examples, the S-CSCF **116** can include the slice identifier **112** associated with the UE **102** in a "service-info" field, custom field, or other field of XML data associated with the TPR message **210**. In other examples, the HSS **120** can include the slice identifier **112** in any other field or data element of the TPR message **210**. The TPR message **210** can also indicate one or more identifiers of the UE **102**, such as a MSISDN, IMSI, and/or identifiers. The application server can return to the S-CSCF **116** a Third Party Registration (TPR) response **212** that confirms receipt of the TPR message **210**.

(58) An application server **118** may, in some examples, also or alternately obtain the slice identifier **112** associated with the UE **102** from the HSS **120**. For example, the application server **118** can send a Subscribe Notifications Request (SNR) **214** associated with the UE **102** to the HSS **120**. The SNR **214** can indicate one or more identifiers of the UE **102**, such as a MSISDN, IMSI, and/or identifiers. The HSS **120** can return to application server **118** a Subscribe Notifications Answer (SNA) **216** that includes the slice identifier **112** associated with the UE **102**. In some examples, the HSS **120** can include the slice identifier **112** associated with the UE **102** in a "service-info" field, custom field, or other field of XML data associated with the SNA **216**. In other examples, the HSS **120** can include the slice identifier **112** in any other field or data element of the SNA **216**.

(59) In some examples, the application server **118** can send the SNR **214** after receiving the TPR message **210** from the S-CSCF **116** that includes the slice identifier **112**, so that the application server **118** can verify that the slice identifier **112** received from the S-CSCF **116** matches the slice identifier **112** provided by the HSS **120** in the SNA **216**. The application server **118** may, in some examples, wait to send the TPR response **212** to the S-CSCF **116** until the application server **118** receives the SNA **216** from the HSS **120**. In other examples, the application server **118** may be configured to not obtain the slice identifier **112** from the HSS **120**, and may be configured to use the slice identifier **112** received in the TPR message **210** from the S-CSCF **116** without verifying the slice identifier **112** with the HSS **120**.

(60) In still other examples, if the application server **118** does not receive the slice identifier **112** associated with the UE **102** from the S-CSCF **116** during IMS registration of the UE **102**, the application server **118** can use the SNR **214** to obtain the slice identifier **112** from the HSS **120** during or after the IMS registration process for the UE **102**. For example, if the application server **118** does not receive the slice identifier **112** associated with the UE **102** during the IMS registration process, and the application server **118** later receives a SIP message that includes the slice identifier **112** associated with the UE **102** as discussed further below with respect to FIG. **3**, the application server **118** may send the SNR **214** to the HSS **120** so that the application server **118** can receive the slice identifier **112** in the SNA **216** and verify that the slice identifier **112** is associated with the UE **102**.

(61) After receiving the slice identifier associated with the UE **102**, from the S-CSCF **116** and/or from the HSS **120**, the application server **118** can cache the slice identifier **112** associated with the UE **102** for future use, for example as discussed further below. For instance, the application server **118** can cache the slice identifier **112** included in the TPR message **210** and/or the SNA **216** in a database, in association with the MSISDN, IMSI, and/or other identifiers of the UE **102**.

(62) FIG. **3** shows an example 300 of a sequence of messages that can be exchanged between elements of the IMS **106** after an IMS registration process for the UE **102**. The messages exchanged between the elements of the IMS **106** in FIG. **3** can include the slice identifier **112** associated with the UE **102**. Accordingly, the IMS elements, such as the P-CSCF **114**, the S-CSCF **116**, and one or more application servers **118**, can use the slice identifier **112** to identify the network slice that the UE **102** is using to access the IMS **106**. The slice identifier **112** included in the messages shown in FIG. **3** can also be the same as the slice identifier **112** used to identify the network slice within the core network **104**, such as an S-NSSAI.

(63) After the UE **102** has registered with the IMS **106**, for instance via the process shown in FIG.

2, the UE **102** can engage in services via the IMS **106**. For example, to engage in a voice call via the IMS **106**, the UE **102** can send an invite message **302** to the P-CSCF **114**. The invite message **302** can, for example, be a SIP INVITE message. The invite message **302** may indicate one or more identifiers of the UE **102**, such as an MSISDN, IMSI, and/or other identifiers.

(64) As described above with respect to FIG. **2**, the P-CSCF **114** can have previously received the slice identifier **112** associated with the UE **102** from the S-CSCF **116** during the IMS registration process, and can have cached the slice identifier **112** associated with the UE **102**. For instance, the P-CSCF **114** can have cached the slice identifier **112** in association with the MSISDN, IMSI, and/or other identifiers of the UE **102**. Accordingly, the P-CSCF **114** can retrieve the cached slice identifier **112** associated with the UE **102**, for instance based on the MSISDN, IMSI, and/or other identifiers of the UE **102** indicated by the invite message **302**.

(65) Based on retrieving the slice identifier **112** associated with the UE **102** from a cache, the P-CSCF **114** can insert the slice identifier **112** associated with the UE **102** into the invite message **302**. For example, the P-CSCF **114** can insert the slice identifier **112** into a "service-info" field, custom field, or other field of XML data of the invite message **302**. In other examples, the P-CSCF **114** can insert the slice identifier **112** into any other field or data element of the invite message **302**. After inserting the slice identifier **112** into the invite message **302**, the P-CSCF **114** can send the invite message **302** on to the S-CSCF **116** assigned to the UE **102**. The S-CSCF **116** can in turn send the invite message **302** to one of the application servers **118**, such as a TAS, that has been selected to implement voice call services for the UE **102**. Accordingly, the application server can perform operations that allow the UE **102** to participate in the voice call.

(66) As described herein, because the P-CSCF **114** inserts the slice identifier **112** associated with the UE **102** into the invite message **302**, the S-CSCF **116** and/or the application servers **118** can use the slice identifier **112** to determine which network slice the UE **102** is using. In some examples, the S-CSCF **116** or an application server **118** can compare the slice identifier **112** inserted into the invite message **302** against the slice identifier **112** previously-cached by the S-CSCF **116** or an application server **118** in association with the UE **102**, and/or retrieve the slice identifier **112** associated with the UE **102** from the HSS **120** as described above, to verify that the UE **102** is using the correct network slice.

(67) Because slice identifiers can be inserted, by the P-CSCF **114**, into invite messages that the S-CSCF **116** and/or the application servers **118** receive, the P-CSCF **114**, the S-CSCF **116**, and/or the application servers **118** can determine how many of the invite messages are associated with corresponding network slices, how often invite messages are associated with corresponding network slices, and/or other types of KPIs associated with the corresponding network slices. For instance, if a TAS receives 1000 invite messages, and 400 of the invite messages include a first slice identifier of a first network slice while 600 of the invite messages include a second slice identifier of a second network slice, the TAS can determine that 40% of the calls associated with that set of 1000 invite messages are being made via the first network slice and that the other 60% of the calls associated with that set of 1000 invite messages are being made via the second network slice.

(68) In other examples, other types of messages exchanged within the IMS **106** can include the slice identifier. For example, if a TAS receives SIP INVITE messages associated with call initiation requests from originating UEs, the TAS can send responsive SIP messages back towards the UEs, such as "180 Ringing" messages indicating that terminating UEs are ringing to alert users of the calls, "200 OK" messages indicating that terminating UEs have answered the calls, "BYE" messages indicating that UEs have terminated calls, and/or other types of messages. Accordingly, based on a cache of slice identifiers associated with the originating UEs, the TAS can insert the slice identifiers into such SIP messages to indicate to the S-CSCF **116** and the P-CSCF **114** when calls associated with corresponding network slices are ringing, answered, terminated, or are associate with other events. Accordingly, elements of the IMS **106** can determine KPIs such as how

often calls associated with certain network slices are answered, how long such calls take to be answered, how long such calls take before being terminated, and/or other KPIs.

(69) Example Architecture

(70) FIG. **4** shows an example system architecture for an IMS element **400** that is configured to use slice identifiers to determine which network slices UEs connected to the IMS **106** are using. The IMS element **400** can be an element of the IMS **106**, such as the P-CSCF **114**, the S-CSCF **116**, and/or an application server **118** discussed above. As shown, the IMS element **400** can include processor(s) **402**, memory **404**, and transmission interface(s) **406**. In some examples, the IMS element **400** can be distinct hardware for the P-CSCF **114**, the S-CSCF **116**, and/or one or more application servers **118**. However, in other examples, the IMS element **400** can be one or more servers, computing systems, or other computing devices that execute the P-CSCF **114**, the S-CSCF **116**, and/or the application servers **118** as software applications or that executes one or more virtual instances of the P-CSCF **114**, the S-CSCF **116**, and/or the application servers **118**.

(71) In various examples, the processor(s) **402** can be a central processing unit (CPU), a graphics processing unit (GPU), both CPU and GPU, or any other type of processing unit. Each of the one or more processor(s) **402** may have numerous arithmetic logic units (ALUs) that perform arithmetic and logical operations, as well as one or more control units (CUs) that extract instructions and stored content from processor cache memory, and then executes these instructions by calling on the ALUs, as necessary, during program execution. The processor(s) **402** may also be responsible for executing all computer-executable instructions and/or computer applications stored in the memory **404**.

(72) In various examples, the memory **404** can include system memory, which may be volatile (such as RAM), non-volatile (such as ROM, flash memory, etc.) or some combination of the two. The memory **404** can also include additional data storage devices (removable and/or non-removable) such as, for example, magnetic disks, optical disks, or tape. Memory **404** can further include non-transitory computer-readable media, such as volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information, such as computer-readable instructions, data structures, program modules, or other data. For example, the memory **404** can store software or firmware elements, such as computer-readable instructions that are executable by the one or more processors **402**. System memory, removable storage, and non-removable storage are all examples of non-transitory computer-readable media. Examples of non-transitory computer-readable media include, but are not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, DVD or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other non-transitory medium which can be used to store desired information and which can be accessed by the IMS element **400**. Any such non-transitory computer-readable media may be part of the IMS element **400**.

(73) The memory **404** can store computer-readable instructions and/or other data associated with operations of the IMS element **400**, including operations associated with determining and using slice identifiers associated with UEs. As an example, the memory **404** can store a slice identifier cache **408** that indicates the slice identifiers associated with UEs. The slice identifier cache **408** can indicate slice identifiers associated with UEs, for instance in association with MSISDNs, IMSIs, and/or other identifiers of the UEs, based on data received by the IMS element **400** from the HSS **120** and/or the S-CSCF **116** as described above. The memory **404** can also include data associated with a slice determiner **410** that is configured to determine, based on a slice identifier associated with a UE, which network slice a UE is using and/or is permitted to use. The memory **404** can also include data associated with a KPI determiner **412** that is configured to determine, in association with one or more network slices that correspond to slice identifiers, one or more types of KPIs and/or billing data associated with the corresponding network slices. The memory **404** can also store other modules and data **414**, which can be utilized by the IMS element **400** to perform or

enable performing any action taken by the IMS element **400**. The other modules and data **414** can include a platform, operating system, firmware, and/or applications, and data utilized by the platform, operating system, firmware, and/or applications.

(74) The transmission interface(s) **406** can include one or more modems, receivers, transmitters, antennas, error correction units, symbol coders and decoders, processors, chips, application specific integrated circuits (ASICs), programmable circuit (e.g., field programmable gate arrays), firmware components, software components, and/or other components through which the IMS element **400** can send data to, and/or receive data from, other IMS elements, other network elements, network functions of the core network **104**, UEs, and/or other elements. For example, if the IMS element **400** is the P-CSCF **114**, the P-CSCF **114** can use one or more transmission interfaces **406** to exchange data with the elements of the core network **104**, the UE **102**, the S-CSCF **116**, and/or other elements. As another example, if the IMS element **400** is the S-CSCF **116**, the S-CSCF **116** can use one or more transmission interfaces **406** to exchange data with the P-CSCF **114**, the application servers **118**, the HSS **120**, and/or other elements. As still another example, if the IMS element **400** is an application server **118**, the application server **118** can use one or more transmission interfaces **406** to exchange data with the S-CSCF **116**, the HSS **120**, and/or other elements.

(75) Example Operations

(76) FIG. **5** shows a flowchart of an example method **500** by which the S-CSCF **116** can provide the slice identifier **112** associated with the UE **102** to the P-CSCF **114** and/or one or more application servers **118** during an IMS registration process for the UE **102**. The IMS registration process can be initiated when the UE **102** sends the registration message **202** to the P-CSCF **114**, as discussed above with respect to FIG. **2**.

(77) At block **502**, the S-CSCF **116** can receive the registration message **202** from the P-CSCF **114**. For example, after the P-CSCF **114** receives the registration message **202** from the UE **102**, the P-CSCF **114** can request that an I-CSCF assign the UE **102** to an S-CSCF, and the P-CSCF **114** can forward the registration message **202** to the S-CSCF **116** selected for the UE **102** by the I-CSCF.

(78) At block **504**, the S-CSCF **116** can retrieve the slice identifier **112** that is associated with the UE **102** from the HSS **120**. For example, the S-CSCF **116** can send the SAR **204** to the HSS **120** to request user data associated with the UE **102**. Because the subscriber provisioning platform **122** can have provisioned both the UDM **110** and the HSS **120** with the slice identifier **112** that is associated with the UE **102**, the HSS **120** can include the slice identifier **112** in the SAA **206** that the HSS **120** returns to the S-CSCF **116**. In some examples, the slice identifier **112** can be included by the HSS **120** in a “service-info” field, custom field, or other field of XML data associated with the SAA **206**.

(79) At block **506**, the S-CSCF **116** can send the slice identifier **112**, obtained by the S-CSCF **116** at block **504**, to the P-CSCF **114**. For example, the S-CSCF **116** can include the slice identifier **112** in the registration response **208** that the S-CSCF **116** sends to the P-CSCF **114** in response to the registration message received at block **502**. The registration response **208** can, for example, be a “200 OK” message that the S-CSCF **116** sends to the P-CSCF **114**, and the S-CSCF **116** can include the slice identifier **112** in a private header or other data field of the “200 OK” message. The P-CSCF **114** can accordingly cache the slice identifier **112** associated with the UE **102** for future use.

(80) At block **508**, the S-CSCF **116** can also send the slice identifier **112**, obtained by the S-CSCF **116** at block **506**, to one or more application servers **118**. For example, the S-CSCF **116** can include the slice identifier **112** in the TPR message **210** that the S-CSCF **116** sends to an application server **118**, for instance in a “service-info” field, custom field, or other field of XML data associated with the TPR message **210**, or any other type of field or data element of the TPR message **210**. The application server **118** can accordingly cache the slice identifier **112** associated with the UE **102** for future use, and/or verify the slice identifier **112** by also obtaining the slice identifier **112** from the

HSS **120** directly via the SNR **214** and SNA **216**. In some examples, the S-CSCF **116** may omit sending the slice identifier **112** to an application server **118** at block **508**. However, in these examples, the application server **118** can separately obtain the slice identifier **112** from the HSS **120** via the SNR **214** and SNA **216**.

(81) After the S-CSCF **116** has provided the slice identifier **112** associated with the UE **102** to the P-CSCF **114** and/or one or more application servers **118** during the IMS registration process as shown in FIG. **5**, the P-CSCF **114**, the S-CSCF **116**, and/or the application servers **118** can at later points in time use the slice identifier **112** to determine the network slice that the UE **102** is using to access services via the IMS **106**. For example, the P-CSCF **114**, the S-CSCF **116**, and/or the application servers **118** can insert the slice identifier **112** associated with the UE **102** into SIP messages exchanged within the IMS **106** to identify and track which network slice is associated with corresponding IMS services and operations.

(82) FIG. **6** shows a flowchart of an example method **600** by which the P-CSCF **114** can, following the IMS registration process for the UE **102**, insert the slice identifier **112** associated with the UE **102** into a message associated with the UE **102**. At block **602**, the P-CSCF **114** can receive the invite message **302** from the UE **102**. The invite message **302** can, for example, be a SIP INVITE message that requests initiation of a call or other type of service or operation via the IMS **106**.

(83) At block **604**, the P-CSCF **114** can retrieve the slice identifier **112** associated with the UE **102** from a cache maintained by the P-CSCF **114**. The P-CSCF **114** can have previously received and cached the slice identifier **112** associated with the UE **102**, for example from the S-CSCF **116** during the IMS registration process, as discussed above with respect to FIG. **5**. Accordingly, the P-CSCF **114** can use an identifier of the UE **102** included in the invite message **302**, such as an MSISDN, IMSI, or other identifier, to retrieve the slice identifier **112** that is associated with the UE **102** from the cache.

(84) At block **606**, the P-CSCF **114** can insert the slice identifier **112**, retrieved from the cache at block **604**, into the invite message **302**. For example, the P-CSCF **114** can insert the slice identifier **112** into a “service-info” field, custom field, or other field of XML data of the invite message **302**, or can insert the slice identifier **112** into any other field or data element of the invite message **302**.

(85) At block **608**, the P-CSCF **114** can forward the invite message **302**, now including the slice identifier **112** associated with the UE **102**, towards one or more destinations within the IMS **106**. For example, the P-CSCF **114** can forward the invite message **302** to the S-CSCF **116** associated with the UE **102**, and the S-CSCF **116** can forward the invite message **302** to an application server **118** that is associated with the UE **102** and a type of service or operations requested in the invite message **302**. Accordingly, the S-CSCF **116** and/or the application server **118** can determine, based on the slice identifier **112** inserted into the invite message **302** by the P-CSCF **114** at block **606**, which network slice the UE **102** is using. In some examples, the S-CSCF **116** and/or the application server **118** can compare the slice identifier **112** inserted into the invite message **302** against a slice identifier previously cached by the S-CSCF **116** and/or the application server **118** for the UE **102**.

(86) FIG. **7** shows a flowchart of an example method **700** by which an IMS element can determine KPIs and/or billing data associated with a network slice based on usage of the network slice by one or more UEs. The IMS element can be the P-CSCF **114**, the S-CSCF **116**, or an application server **118**.

(87) At block **702**, the IMS element can determine the slice identifier **112** associated with the UE **102**. In some examples, the IMS element can determine the slice identifier **112** associated with the UE **102** during an IMS registration process, as discussed above with respect to FIG. **2** and FIG. **5**. In other examples, the IMS element can determine the slice identifier **112** associated with the UE **102** after an IMS registration process, for instance based on a previously-cached instance of the slice identifier **112** for the UE **102** and/or based on the P-CSCF **114** or another IMS element inserting the slice identifier **112** into a message being sent through the IMS **106**.

(88) At block **704**, the IMS element can determine whether the slice identifier **112** associated with

the UE **102** corresponds with a network slice that the IMS element is configured to use to provide services to the UE **102**. For example, if the IMS element has been reserved for use with one or more particular network slices, the IMS element can determine whether the slice identifier **112** associated with the UE **102** corresponds with one of those network slices. As another example, if an invite message or other type of message is requesting a particular type of service that can be provided by the IMS element, but the IMS element has been configured to perform that particular type of service in association with one or more particular network slices or types of network slices, the IMS element can determine whether the slice identifier **112** associated with the UE **102** corresponds with one of those network slices or types of network slices.

(89) If the IMS element determines that the slice identifier **112** associated with the UE **102** does not correspond with a network slice that the IMS element is configured to use to provide services to the UE **102** (Block **704**—No), the IMS element can at block **706** cause the UE **102** to be redirected to one of those network slices, or to a different instance of the IMS element that is configured to perform services in association with the network slice that corresponds to the slice identifier **112** associated with the UE **102**. For example, if the IMS element has been reserved for use with one or more particular network slices or types of network slices, the IMS element may initiate a re-registration process for the UE **102**, such that the UE **102** is re-registered with the core network **104** and/or the IMS **106** and becomes associated with one of the particular network slices or types of network slices for which the IMS element is reserved. As another example, such a re-registration process may cause the UE **102** to be re-assigned in the IMS **106** to a different instance of the IMS element that is associated with the network slice that the UE **102** is already using.

(90) If the IMS element instead determines that the slice identifier **112** associated with the UE **102** does correspond with a network slice that the IMS element is configured to use to provide services to the UE **102** (Block **704**—Yes), the IMS element can begin performing operations associated with such services. At block **708**, the IMS element can track such operations in association with the UE **102** and with the network slice that corresponds with the slice identifier **112**. The IMS element can also track the same or similar operations in association with other UEs that are also associated with the same the slice identifier **112** at block **708**, as those other UEs can also be associated with the same network slice as the UE **102**.

(91) Accordingly, at block **710** the IMS element can generate KPIs, billing data, and/or other types of information associated with the network slice, based on tracking operations performed for the UE **102** and other UEs in association with the network slice at block **708**. For example, the IMS element can generate KPIs indicating how often the network slice is being used by UEs to engage in one or more types of communication sessions or IMS services, which types of communication sessions or IMS services are being used by UEs via the network slice, total numbers of instances of communication sessions or IMS services that UEs are engaging in via the network slice over periods of time, how usage of the network slice in association with the IMS compares to a total capacity of the network slice, latency metrics associated with communication sessions or IMS services that UEs are engaging in via the network slice, throughput metrics associated with communication sessions or IMS services that UEs are engaging in via the network slice, and/or other types of KPIs. As another example, the IMS element can generate billing data based on the KPIs or other metrics that indicate how UEs are using the network slice to engage in communication sessions or IMS services.

(92) At block **712**, the IMS element can determine whether one or more of the KPIs determined at block **710** in association with the network slice meet corresponding goals defined in an SLA for the network slice. If the IMS element determines that the KPIs associated with the network slice are not meeting the corresponding goals defined in the SLA, the IMS element may output an alert or other notification associated with the network slice at block **714**. The IMS element can, for example, send the alert to another IMS element, to an owner or operator of the IMS **106**, to an element of the core network **104**, and/or to any other destination.

(93) At block **714**, the IMS element can also output the KPIs and/or billing data associated with the network slice generated at block **710**. For example, the IMS element can output the KPIs and/or billing data associated with the network slice alert to another IMS element, to an owner or operator of the IMS **106**, to an element of the core network **104**, and/or to any other destination.
(94) Although FIG. **7** shows a single IMS element generating KPIs and/or billing data associated with a network slice, and/or comparing the KPIs against goals defined in an SLA for the network slice, in other examples multiple IMS elements can send tracked data about operations performed by those IMS elements to a central server or other network element. The central server or other network element can aggregate the data to determine KPIs and/or billing data associated with the network slice as discussed with respect to block **710**, based on operations performed by multiple IMS elements. The central server or other network element can also compare the KPIs against SLA goals as discussed with respect to block **712**, and/or output corresponding alerts, KPI data, and/or billing data as discussed with respect to block **714** and block **716**.
(95) The operations of FIG. **7** can also be performed by one or more IMS elements in association with multiple network slices. For example, if the IMS element is configured to perform services for UEs in association with multiple network slices, the IMS element can use the method **700** shown in FIG. **7** to separate track operations associated with different network slices, to determine different KPIs and/or different billing data in association with different network slices, and/or to output corresponding alerts, KPI data, and/or billing data in association with different network slices.
CONCLUSION
(96) Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example embodiments.

Claims

1. A method, comprising: receiving, by a Serving Call Session Control Function (S-CSCF) of an Internet Protocol (IP) Multimedia Subsystem (IMS), a registration message associated with a user equipment (UE) from a Proxy Call Session Control Function (P-CSCF) of the IMS; retrieving, by the S-CSCF in response to receiving the registration message, a slice identifier associated with the UE from a Home Subscriber Server (HSS), wherein the slice identifier: corresponds to a network slice associated with the UE, and is used within a core network to identify the network slice; sending, by the S-CSCF, the slice identifier associated with the UE to the P-CSCF in a registration response message; and sending, by the S-CSCF, the slice identifier associated with the UE to an application server of the IMS.
2. The method of claim 1, wherein retrieving the slice identifier associated with the UE comprises: sending, by the S-CSCF, a Server Assignment Request (SAR) to the HSS; and receiving, by the S-CSCF, a Server Assignment Answer (SAA) from the HSS, wherein the SAA includes the slice identifier associated with the UE.
3. The method of claim 2, wherein the SAA includes the slice identifier associated with the UE in a service-info field of Extensible Markup Language (XML) data.
4. The method of claim 1, further comprising verifying, by the application server, the slice identifier associated with the UE by: sending, by the application server, a Subscribe Notifications Request (SNR) to the HSS; and receiving, by the application server, a Subscribe Notifications Answer (SNA) from the HSS, wherein the SNA includes the slice identifier associated with the UE.
5. The method of claim 1, further comprising: storing, by the P-CSCF, the slice identifier associated with the UE in a cache of the P-CSCF, in association with an identifier of the UE; receiving, by the P-CSCF, an invite message from the UE; retrieving, by the P-CSCF, the slice identifier associated with the UE from the cache; inserting, by the P-CSCF, the slice identifier associated with the UE

into the invite message; and forwarding, by the P-CSCF, the invite message to the S-CSCF, wherein the invite message includes the slice identifier associated with the UE.
6. The method of claim 5, further comprising forwarding, by the S-CSCF, the invite message to the application server of the IMS, wherein the invite message includes the slice identifier associated with the UE.
7. The method of claim 6, further comprising verifying, by at least one of the S-CSCF, the P-CSCF, or the application server, that the at least one of the S-CSCF, the P-CSCF, or the application server is configured to perform operations for the UE in association with the network slice that corresponds to the slice identifier.
8. The method of claim 1, further comprising identifying, by at least one of the S-CSCF, the P-CSCF, or the application server of the IMS, operations performed by the at least one of the S-CSCF, the P-CSCF, or the application server in association with the network slice, based on one or more messages associated with the UE or one or more other UEs that include the slice identifier, and generating, by the at least one of the S-CSCF, the P-CSCF, or the application server, at least one of a key performance indicator (KPI) or a billing record associated with usage of the network slice.
9. The method of claim 1, wherein: the HSS was provisioned with the slice identifier associated with the UE by a subscriber provisioning platform, and the subscriber provisioning platform also provisioned the slice identifier associated with the UE to a Unified Data Management (UDM) function in the core network.
10. The method of claim 9, wherein the subscriber provisioning platform provisioned the slice identifier associated with the UE to the HSS in a service-info field of Extensible Markup Language (XML) data.
11. A system, comprising: a Home Subscriber Server (HSS) that stores, based on being provisioned with user data by a subscriber provisioning platform, a slice identifier associated with a user equipment (UE), wherein the slice identifier: corresponds to a network slice associated with the UE, and is used within a core network to identify the network slice; and a Proxy Call Session Control Function (P-CSCF) of an Internet Protocol (IP) Multimedia Subsystem (IMS); an application server of the IMS; and a Serving Call Session Control Function (S-CSCF) of the IMS, wherein the S-CSCF is configured to: retrieve the slice identifier associated with the UE from the HSS in response to receiving a registration message associated with the UE from the P-CSCF; and send the slice identifier associated with the UE to the P-CSCF in a registration response message, wherein the P-CSCF is configured to: based on receiving the registration response message, store the slice identifier associated with the UE in a cache, in association with an identifier of the UE; insert the slice identifier associated with the UE into an invite message received from the UE; and forward the invite message, including the slice identifier associated with the UE, towards at least one of the S-CSCF or the application server, wherein the S-CSCF is further configured to, in response to retrieving the slice identifier associated with the UE from the HSS, send the slice identifier associated with the UE to the application server.
12. The system of claim 11, wherein the application server is configured to: send a Subscribe Notifications Request (SNR) associated with the UE to the HSS; and receive a Subscribe Notifications Answer (SNA) from the HSS, wherein the SNA includes the slice identifier associated with the UE.
13. The system of claim 11, wherein at least one of the S-CSCF, the P-CSCF, or the application server is configured to verify that the at least one of the S-CSCF, the P-CSCF, or the application server is configured to perform operations for the UE in association with the network slice that corresponds to the slice identifier.
14. The system of claim 11, wherein at least one of the S-CSCF, the P-CSCF, or the application server is configured to: identify operations performed by the at least one of the S-CSCF, the P-CSCF, or the application server in association with the network slice, based on one or more

messages associated with the UE or one or more other UEs that include the slice identifier, and generate at least one of a key performance indicator (KPI) or a billing record associated with usage of the network slice.

15. One or more non-transitory computer-readable media storing computer-executable instructions associated with a Serving Call Session Control Function (S-CSCF) of an Internet Protocol (IP) Multimedia Subsystem (IMS) that, when executed by one or more processors associated with the S-CSCF, cause the one or more processors to: receive a registration message associated with a user equipment (UE) from a Proxy Call Session Control Function (P-CSCF) of the IMS; retrieve, in response to receiving the registration message, a slice identifier associated with the UE from a Home Subscriber Server (HSS), wherein the slice identifier corresponds to a network slice associated with the UE, and is used within a core network to identify the network slice; and send the slice identifier associated with the UE to the P-CSCF in a registration response message, wherein the HSS was provisioned with the slice identifier associated with the UE by a subscriber provisioning platform, and wherein the subscriber provisioning platform also provisioned the slice identifier associated with the UE to a Unified Data Management (UDM) function in the core network.

16. The one or more non-transitory computer-readable media of claim 15, wherein the computer-executable instructions further cause the one or more processors to send the slice identifier associated with the UE to an application server of the IMS.

17. The one or more non-transitory computer-readable media of claim 15, wherein the computer-executable instructions further cause the one or more processors to: receive, from the P-CSCF, an invite message associated with the UE, wherein the invite message includes a copy of the slice identifier associated with the UE that the P-CSCF inserted into the invite message; and forward the invite message, including the copy of the slice identifier associated with the UE, to an application server of the IMS.