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5G REMOTE PLMN CAPABILITY SHARING AND SERVICE DISCOVERY DELEGATION

Abstract

Various embodiments of the present technology generally relate to systems and methods for remote mobile network capability sharing, and delegation of service discovery and selection to the remote mobile network, such as from a visited or roaming network to a home network. A first public land mobile network (PLMN) system may send, via a local network repository function (NRF), a request for capability details of a second PLMN, the capability details including an ability of the second PLMN to handle delegated service discovery and selection. The first PLMN may receive the capability details, and send, from the first PLMN to the second PLMN, a delegated discovery and network function (NF) selection request directing a service communications proxy (SCP) of the second PLMN to determine a producer NF of the second PLMN to process a service request from a consumer NF of the first PLMN.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION [0001] The present application claims priority to pending U.S. provisional patent application, Application No. 63/554,649, filed Feb. 16, 2024, entitled “SCP Deployment Topology and Capability Discovery in Different PLMN 5G Core Networks for Roaming Request Routing”, the contents of which are hereby incorporated by reference in their entirety.

TECHNICAL FIELD
[0002] Various embodiments of the present technology generally relate to management of roaming service between different mobile networks, such as fifth generation (5G) communications networks. More specifically, embodiments of the present technology relate to systems and methods for improved NF selection and routing between visitor or visited networks and home networks.
BACKGROUND
[0003] Communications networks can be used to connect remote systems and devices, allowing for distributed and efficient processing, resource use, and intercommunication. User equipment (UE) can connect to a communications network through a network service provider or network operator. A UE or its associated user may subscribe to a particular network operator, which may provide communication service, network infrastructure, or both, within a designated region or area, which may be referred to as a home network. If the subscriber leaves the area of the home network, their UE may still be able to connect to a visited or visitor network as a roaming user. The visited network may communicate with the roaming subscriber's home network to manage service, billing, or other aspects of the roaming UE's network service. A network domain may be referred to as a public land mobile network (PLMN), which may include a combination of wireless communication services offered by a specific operator in a specific country or region (often referred to as a cellular network). A visitor network may be referred to as a visitor PLMN (VPLMN or V-PLMN) and a home network may be referred to as a home PLMN (HPLMN or H-PLMN).
[0004] Network nodes within a 5GC (5G core) network may take the form of network functions (NFs), service communications proxies (SCPs), security edge protection proxies (SEPPs), or other nodes, generally referred to as NFs. Producer NFs (PNF, NF-P, or NFp) may provide a service for consumer NFs (CNF, NF-C, or NFc). Under 3GPP (3rd Generation Partnership Project) standards, a consumer NF may select a producer NF to which to route a service request, or under certain deployment models, the NF-P selection process may be delegated to an SCP. When a visitor network is communicating with a home network (e.g., during a roaming session), service requests may be sent from a visitor NF-C or SCP to a home network NF-P.
[0005] However, SCP and consumer NFs in one network may not be aware of another network's supported deployment Model (B, C, or D, etc.) to support 5G SBI (service-based interface) communications. If a visitor NF attempts to take advantage of SBI communication features on the home network that the home network deployment model does not support (or vice versa), it may result in a mismatch and the service request may fail. Therefore, service discovery and routing may be handled internally at the visitor network. In case of any roaming request routing attempt failure, alternate NF selection and rerouting may be performed in the visitor network only, instead of at the home network, which may introduce delay in service request routing success, and successful responses may be delayed to the consumer NFs.

[0006] Meanwhile, a home network may prefer to perform discovery and selection of NFp in the home domain for various reasons. For example, the home domain may wish to avoid disclosing information about candidate NFp that may be sensitive (e.g. load and capacity info, topology info, etc.). The home domain may wish to apply consistent discovery and selection policies for requests issued from other domains, just as for those issued within the same domain (e.g., to achieve harmonized policies for intra- and inter-PLMN requests). Further, the home domain may wish to deploy its own discovery or selection policies, independently from NF implementations in other domains, including the possibility to use operator-specific attributes of the home network. Accordingly, there exists a need for improved processes for service discovery and routing across network domains, while allowing the HPLMN to hide deployment information while performing unified discovery, selection, and routing to its own NF producers.

[0007] The information provided in this section is presented as background information and serves only to assist in any understanding of the present disclosure. No determination has been made and no assertion is made as to whether any of the above might be applicable as prior art with regard to the present disclosure.

BRIEF SUMMARY OF THE INVENTION

[0008] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used as an aid in determining the scope of the claimed subject matter.

[0009] Various embodiments herein relate to systems, methods, and computer-readable storage media for performing configuration data management. In an embodiment, a public land mobile network (PLMN) system may comprise one or more processors, and a memory having stored thereon instructions that, upon execution by the one or more processors, cause the one or more processors to delegate discovery and routing from a first PLMN to a second PLMN. The one or more processors may send, via a first PLMN, a request for capability details of a second PLMN, the capability details including an ability of the second PLMN to handle delegated service discovery and selection, and receive, at the first PLMN, the capability details. The one or more processors may send, from the first PLMN to the second PLMN based on the capability details, a delegated discovery and network function (NF) selection request directing a remote service communications proxy (SCP) of the second PLMN to determine a producer NF of the second PLMN to process a service request from a consumer NF of the first PLMN, and receive a service request response at the first PLMN from the second PLMN in response to the delegated discovery and NF selection request.

[0010] In some examples, the PLMN system may send the request for capability details via a local network repository function (NRF) of the first PLMN to a remote NRF of the second PLMN, and receive the capability details at the local NRF from the remote NRF. The PLMN system may send the request for capability details via a GET request for a custom parameter, and send a subscription request, from the local NRF to the remote NRF, to receive an update when the capability details of the second PLMN change. In some examples, the PLMN system may provide the capability details from the local NRF to a local SCP of the first PLMN in response to a remote PLMN capability request from the local SCP. Further, the PLMN system may receive the service request at the local SCP from the consumer NF, and send the delegated discovery and NF selection request from the local SCP to the remote SCP in response to the service request. In some examples, the PLMN system may send a first NF discovery request from the local NRF to the remote NRF to determine the remote SCP, and send the delegated discovery and NF selection request to the remote SCP based on a response to the first NF discovery request received from the remote NRF. The PLMN system may the delegated discovery and NF selection request directs the remote SCP to determine the producer NF of the second PLMN to process a service request, including issue a second NF discovery request to the remote NRF to determine a plurality of producer NFs of the second PLMN

configured to process the service request, perform a selection of the producer NF from the plurality of producer NFs, perform a first routing attempt of the service request to the producer NF, and when the first routing attempt fails, perform an alternate routing attempt to an alternate producer NF from the plurality of producer NFs, receive the service request response from a successful one of the first routing attempt and the alternate routing attempt, and forward the service request response to the local SCP. In some examples, the first PLMN has a model D deployment, the model D deployment indicating a mobile network including an SCP configured to perform delegated discovery and routing, and the second PLMN has a model D deployment. In some embodiments, the first PLMN has a model C deployment indicating a mobile network not configured to perform delegated discovery and routing, and the second PLMN has a model D deployment indicating a mobile network including an SCP configured to perform delegated discovery and routing. The PLMN system may perform an initial service request routing operation, including receive a first NF discovery request from the consumer NF at the local NRF for information on the producer NF to process the service request, perform NF discovery between the local NRF to the remote NRF for a plurality of producer NFS configured to process the service request, provide a discovery response to the consumer NF including details on the plurality of producer NFs, and receive an NF routing request from the consumer NF at the local SCP, the NF routing request including a discovery header identifying the producer NF as a target NF of the NF routing request. The PLMN system may forward the NF routing request from the local SCP to the remote SCP, directing the remote SCP to make a first routing attempt to the producer NF, and when the first routing attempt fails, perform an NF discovery to the remote NRF based on the discovery header, perform an alternate routing attempt to an alternate producer NF from the plurality of producer NFs based on the NF discovery, and return a success response to the first PLMN, the success response including a location identifier of the alternate producer NF. The PLMN system may then store, at the consumer NF, the location identifier. Further, the PLMN system may perform a subsequent service request routing operation, including receive a subsequent NF routing request from the consumer NF at the local SCP, the subsequent NF routing request including a routing binding header identifying the alternate producer NF as the target NF of the subsequent NF routing request based on the location identifier, and forward the subsequent NF routing request from the local SCP to the remote SCP, directing the remote SCP to make a first subsequent routing attempt to the alternate producer NF, when the first subsequent routing attempt fails, perform a second NF discovery to the remote NRF based on the routing binding header, perform a subsequent alternate routing attempt to the producer NF based on the NF discovery, and return a subsequent success response to the first PLMN, the subsequent success response including a location identifier of the producer NF.
[0011] In an alternative embodiment, a method may comprise operating a first public land mobile network (PLMN) to perform delegated discovery and routing to a second PLMN, comprising sending, via the first PLMN, a request for capability details of the second PLMN, the capability details including an ability of the second PLMN to handle delegated service discovery and selection. The method may comprise receiving, at the first PLMN, the capability details, sending, from the first PLMN to the second PLMN based on the capability details, a delegated discovery and network function (NF) selection request directing a remote service communications proxy (SCP) of the second PLMN to determine a producer NF of the second PLMN to process a service request from a consumer NF of the first PLMN, and receiving a service request response at the first PLMN from the second PLMN in response to the delegated discovery and NF selection request.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0012] Many aspects of the disclosure can be better understood with reference to the following

drawings. The components in the drawings are not necessarily drawn to scale. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views. While several embodiments are described in connection with these drawings, the disclosure is not limited to the embodiments disclosed herein.

[0013] FIG. **1** is a diagram of an operational environment of a system configured to perform 5G remote PLMN capability sharing and service discovery delegation, in accordance with certain embodiments of the present disclosure;

[0014] FIG. **2** is a flow diagram of an example system performing traffic flow for model D delegated request routing in a roaming scenario, in accordance with certain embodiments of the present disclosure;

[0015] FIG. **3** is a flow diagram of an example system performing traffic flow for model C request routing in a roaming scenario, in accordance with certain embodiments of the present disclosure;

[0016] FIG. **4** is a flow diagram of an example system configured to perform 5G remote PLMN capability sharing and service discovery delegation, in accordance with certain embodiments of the present disclosure;

[0017] FIG. **5** is a flow diagram of an example system configured to perform 5G remote PLMN capability sharing and service discovery delegation, in accordance with certain embodiments of the present disclosure;

[0018] FIG. **6** is a flow diagram of an example system configured to perform 5G remote PLMN capability sharing and service discovery delegation, in accordance with certain embodiments of the present disclosure;

[0019] FIG. **7** is a flow diagram of an example system configured to perform 5G remote PLMN capability sharing and service discovery delegation, in accordance with certain embodiments of the present disclosure; and

[0020] FIG. **8** illustrates a computing system configured to perform 5G remote PLMN capability sharing and service discovery delegation, in accordance with some embodiments of the present technology.

[0021] Some components or operations may be separated into different blocks or combined into a single block for the purposes of discussion of some of the embodiments of the present technology. Moreover, while the technology is amenable to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and are described in detail below. The intention, however, is not to limit the technology to the particular embodiments described. On the contrary, the technology is intended to cover all modifications, equivalents, and alternatives falling within the scope of the technology as defined by the appended claims.

DETAILED DESCRIPTION

[0022] In the following detailed description of certain embodiments, reference is made to the accompanying drawings which form a part hereof, and in which are shown by way of illustration of example embodiments. It is also to be understood that features of the embodiments and examples herein can be combined, exchanged, or removed, other embodiments may be utilized or created, and structural changes may be made without departing from the scope of the present disclosure. The following description and associated figures teach the best mode of the invention. For the purpose of teaching inventive principles, some aspects of the best mode may be simplified or omitted.

[0023] In accordance with various embodiments, the methods and functions described herein may be implemented as one or more software programs running on a computer processor or controller. Dedicated hardware implementations including, but not limited to, application specific integrated circuits, programmable logic arrays, and other hardware devices can likewise be constructed to implement the methods and functions described herein. Methods and functions may be performed by modules or nodes, which may include one or more physical components of a computing device (e.g., logic, circuits, processors, etc.) configured to perform a particular task or job, or may include instructions that, when executed, can cause a processor to perform a particular task or job, or any combination thereof. Further, the methods described herein may be implemented as a computer readable storage medium or memory device including instructions that, when executed, cause a processor to perform the methods.

[0024] FIG. **1** is a diagram of a system **100** configured to perform 5G remote PLMN capability sharing and service discovery delegation, in accordance with certain embodiments of the present disclosure. The example system **100** may include 5G mobile networks implementing 3GPP (3rd Generation Partnership Project) communication standards (e.g., using the TS 33.510 technical specification), although the present disclosure may apply to other communication networks. The system **100** may include a UE **106** connected to a visited or visitor public land mobile network (V-PLMN) **102**, which in turn may exchange data with a home PLMN (H-PLMN) **104**. Components of system **100** may communicate via network connectivity components **108**.

[0025] UE **106** may be a device, system, or module that may utilize the resources of the V-PLMN **102** and H-PLMN **104**, such as to establish mobile communications with another UE or to connect to the internet. UE **106** may include mobile devices such as cell phones, tablets, or modems.

[0026] Network connectivity components **108** may comprise components that enable communication over communication links, such as network cards, ports, radio frequency (RF) modules, telecommunications channels, cell towers, processing circuitry and software, or other communication components. Network connectivity components **108** may include metallic, wireless, cellular, or optical links, using various communication formats and protocols. In some examples, network connectivity components **108** may simply be referred to as a “network” by which systems or modules are connected or communicate.

[0027] V-PLMN **102** and H-PLMN **104** may each include a combination of wireless communication services offered by a specific operator in a specific country or region (often referred to as a cellular network). Which PLMN is a “home” network or a “visitor” network (in which a UE **106** is roaming) may depend upon which network operator a UE **106** or user is subscribed to. Each of V-PLMN **102** and H-PLMN **104** may include a number of network functions (NFs) to provide a resource or functionality to various components and UEs **106** of the wireless network. The NFs may include a network repository function or NF repository function (NRF), such as home-NRF (H-NRF) **122** and visited-NRF (V-NRF) **110**, a service communications proxy (SCP), such as home-SCP (H-SCP) **120** and visited-SCP (V-SCP) **114**, and various NFs, such as a first consumer NF (NF-C1) **116**, a first producer NF (NF-P1) **124**, and a second producer NF (NF-P2) **126**. In addition, each network may include a security edge protection proxy (SEPP), such as home-SEPP (H-SEPP) **118** and visited-SEPP (V-SEPP) **112**. The components of V-PLMN **102** and H-PLMN **104**, including the physical devices implementing them, may be co-located, remotely distributed, or any combination thereof.

[0028] Each or any of UE **106**, H-NRF **122**, V-NRF **110**, H-SCO **120**, V-SCP **114**, NF-C1 **116**, NF-P1 **124**, NF-P2 **126**, H-SEPP **118**, V-SEPP **112**, and network **108** may be implemented via computers, servers, hardware and software modules, or other system components. The elements of system **100** may include components hosted or situated in the cloud, and implemented as software modules potentially distributed across one or more server devices or other physical components.

[0029] A network repository function or NF repository function (NRF) **110**, **122** may be a monitoring element which includes and maintains a repository of information on the NF elements of the network, including what services or resources each provides, and potentially metadata provided by the NF. For example, NFs may register with the NRF to provide registration information and metadata regarding the NF to the NRF for storing in the repository. Once an NF is registered with the NRF, the NRF may provide information regarding the NF in response to discovery requests. For example, a consumer NF may send a discovery request to the NRF regarding an SCP **114**, **120** within the network, and the NRF may issue a discovery response providing identifying information and metadata for SCPs in the repository matching the request.

[0030] A security edge protection proxy (SEPP) **112**, **118** may be used to protect control plane traffic that is exchanged between different PLMNs **102**, **104**. A SEPP may perform message filtering, policing, and topology hiding for all API (application program interface) messages. Messages between SEPPs may be sent via an N32 interface (e.g., N32-C or N32-F), which may be an inter-PLMN interface standard. The transmissions may use a transport layer security (TLS) connection and may therefore be encrypted. A SEPP may use a different TLS connection to send messages to elements of its own network. Communications between components of V-PLMN **102** and components of H-PLMN **104** may be transmitted by way of V-SEPP **112** and H-SEPP **118**.
[0031] SCP **114** and **120** may act as routing agents within a network (e.g., V-PLMN **102** or H-PLMN **104**) of system **100**. An SCP **114**, **120** may subscribe with the local NRF **110**, **122** and obtain reachability and service profile information regarding producer NF service instances within a PLMN. Consumer NFs **116** may connect to the SCP **114**, and the SCP may load balance traffic among producer NF service instances that provide the required service, or may directly route the traffic to a specified producer NF.
[0032] A network node or NF that provides service may be referred to as a producer NF (e.g., NF-P1 **124**, NF-P2 **126**), while a network node or NF that consumes service may be referred to as a consumer NF (e.g., NF-C1 **116**). A network function can be both a producer NF and a consumer NF depending on whether it is consuming or providing service in a given exchange. So for example, NRF **110** may operate as a producer NF and SCP **114** may operate as a consumer NF in an exchange where NRF **110** is providing details on NF profiles to SCP **114**. Generic consumer NFs **116** and producer NFs **124**, **126** are depicted in system **100** in addition to specific example NFs (which may act as consumers or producers) such as NRFs **110**, **122**, SEPPs **112**, **118**, and SCPs **114**, **120**.
[0033] 3GPP may provide a number of different implementation or deployment models for 5G networks, such as models A, B, C, and D. The models may define aspects of the network's infrastructure and capabilities of its components. Model A may include no NRF. Model B may include an NRF, but may not include SCPs for traffic routing and balancing. Model C may include an NRF and an SCP for routing, but may not include an SCP configured for delegated discovery and indirect communication. Model D may include an NRF and an SCP configured to perform delegated discovery-based routing. Delegated discovery and routing may refer to a situation in which a consumer NF specifies to the SCP what service the consumer is seeking and provides the SCP with the service request. The SCP may then determine NF-P options for servicing the request, may select the NF-P to send the request to, and then may select alternate NF-Ps or routing if the initial request(s) fails. In a model D delegated discovery scenario, a consumer NF may send a 5G SBI service request along with NF-P selection query parameters (e.g., in discovery headers) to the SCP. The SCP may then perform NF discovery with the NRF as per the received discovery headers from the consumer NF, and sends the 5G SBI service request to the selected producer NF. The producer NF is expected to process the received 5G SBI service request and send the response. Without delegated routing, a consumer NF may be required to select the NF-P itself, and then reselect alternates when an initial request fails, which may add delays to successful service requests and reduce the quality of service of a user session.
[0034] V-SCP **114** and NF-C1 **116** from V-PLMN **102** may not be aware of what deployment model is supported by H-PLMN **104**. If delegated discovery requests were sent to a PLMN that did not support them, the requests may fail and cause delays and failures in service sessions. FIGS. **2** and **3** provide example embodiments in which producer NF discovery, selection, and routing from V-PLMN **102** to access a producer NF within H-PLMN **104** may need to be performed within V-PLMN **102** by V-SCP **114** or NF-C1 **116**. Throughout this disclosure, examples are made of a consumer NF within V-PLMN **102** accessing a producer NF within H-PLMN **104**, and potentially discovering capabilities and delegating selection and routing to H-PLMN **104**, but it should be understood that the reverse is also applicable, with components of H-PLMN **104** discovering and

delegating to V-PLMN **102**.

[0035] FIG. **2** is a flow diagram of an example system **200** performing traffic flow for model D delegated request routing in a roaming scenario, in accordance with certain embodiments of the present disclosure. In particular, system **200** may include a V-PLMN **202** having an NF-C1 **216**, V-SCP **214**, V-NRF **210**, and V-SEPP **212**, as well as an H-PLMN **204** including an H-SEPP **218**, H-SCP **220**, H-NRF **222**, NF-P1 **224**, and NF-P2 **226**. The components of V-PLMN **202** and H-PLMN **204** may substantially correspond to components of V-PLMN **102** and H-PLMN **104** of FIG. **1**.

[0036] In the example of FIG. **2**, V-PLMN **202** may be a model D network, meaning NF discovery and routing may be delegated to V-SCP **214**. NF-C1 **216** may issue a service request with NF discovery and selection parameters in order to delegate discovery to V-SCP **214**, at **230**. Based on the request, V-SCP **214** may request producer NF discovery to V-NRF **210**, at **232**. V-NRF **210** may need to perform, at **234**, discovery to H-NRF **222** (via V-SEPP **212** and H-SEPP **218**, with potential routing through H-SCP **220**) to discover details about producer NFs (NF-P1 **224** and NF-P2 **226**) within H-PLMN **204**. Performing NF discovery from V-PLMN **202** to H-PLMN **204** may include the H-PLMN **204** being required to disclose details about the topology or capabilities of NFs within its own network, which an operator of H-PLMN **204** may prefer not to share. The discovery details may be relayed from V-NRF **222** to V-SCP **214**, at **236**. At **238**, V-SCP **214** may initially select to send the NF service request to NF-P1 **224** based on the discovery and selection parameters received from NF-C1 **216** at **230**. V-SCP **214** may send an initial routing attempt to access NF-P1 **224** within H-PLMN **204**, at **240**. V-SCP **214** may receive a response at **242**, indicating either that the first routing attempt was successful, or that the routing failed or encountered an error. If the first routing attempt succeeded, a successful routing response may be sent from V-SCP **214** to NF-C1 **216**, at **244**. However, if the first routing request fails, then V-SCP **214** may need to perform reselection to NF-P2 **226**, at **246**, and resend the request, at **248**. The V-SCP **214** may receive a success response at **250**, and forward the success response to NF-C1 **216**, at **252**. A successful response may include service data or other information requested from an NF producer by NF-C1 **216**. All the transmissions between V-PLMN **202** and H-PLMN **204** may need to be routed between SEPPs **212** and **218** and may generally introduce undesirable delays for service requests. FIG. **3** provides another example of producer NF discovery and routing performed within a visited network.

[0037] FIG. **3** is a flow diagram of an example system **300** performing traffic flow for model C request routing in a roaming scenario, in accordance with certain embodiments of the present disclosure. In particular, system **300** may include a V-PLMN **302** having an NF-C1 **316**, V-SCP **314**, V-NRF **310**, and V-SEPP **312**, as well as an H-PLMN **304** including an H-SEPP **318**, H-SCP **320**, H-NRF **322**, NF-P1 **324**, and NF-P2 **326**. The components of V-PLMN **302** and H-PLMN **304** may substantially correspond to components of V-PLMN **102** and H-PLMN **104** of FIG. **1**.

[0038] The example system **300** may be similar to the example system **200** of FIG. **2**, except V-PLMN **202** may be a model C configuration where NF-C1 **316** does not delegate discovery to V-SCP **314**. Accordingly, NF-C1 **316** may need to perform producer selection and re-selection, potentially introducing even further delays. NF-C1 **316** may issue an NF discovery request to V-SCP **314**, at **330**. At **332**, V-SCP **314** may send the NF discovery request to V-NRF **310**. V-NRF **210** may need to perform, at **334**, discovery to H-NRF **322** (via V-SEPP **312** and H-SEPP **318**, with potential routing through H-SCP **320**) to discover details about producer NFs (NF-P1 **324** and NF-P2 **326**) within H-PLMN **304**. The discovery details may be relayed from V-NRF **322** to V-SCP **314**, at **336**, which V-SCP **314** may forward to NF-C1 **316**, at **338**. Based on the discovery response, NF-C1 **316** may initially select to send the NF service request to NF-P1 **324**. NF-C1 **316** may send the service routing request for NF-P1 **324** to V-SCP **314**, at **342**, which may perform the initial routing attempt to access NF-P1 **324** within H-PLMN **304**, at **344**. V-SCP **314** may receive a response at **346**, indicating either that the first routing attempt was successful, or that the routing failed or encountered an error. V-SCP **314** may forward the first routing attempt results to NF-C1

316, at **348**. If the first routing attempt succeeded, the service request may be completed. However, if the first routing request fails, then NF-C1 **316** may need to perform reselection to NF-P2 **326**, at **350**, and send an alternate routing request to V-SCP **314**, at **252**. The V-SCP **314** perform the alternate routing attempt, at **354**, may receive a success response at **356**, and forward the success response to NF-C1 **316**, at **358**. As with system **200**, all the transmissions in system **300** between V-PLMN **302** and H-PLMN **304** may need to be routed between SEPPs **312** and **318** and may generally introduce undesirable delays for service requests.

[0039] In addition to the potential producer selection and routing delays described above for either scenario of FIG. **2** or **3**, service discovery and requests may be handled according to the processes of V-PLMN **202** or **302**, and may not be handled in the same manner as requests and communications within H-PLMN **204** or **304**. H-PLMN **204** or **304** may prefer that all requests and messaging be handled in a consistent manner, and therefore discovery and routing would preferably be performed within H-PLMN **204** or **304**, even for requests originating from V-PLMN **202** or **304**.

[0040] Returning to FIG. **1**, as shown in regards to FIGS. **2** and **3**, mobile network implementations in which V-SCP **114** is not aware of the deployment model of H-PLMN **104** to support 5G SBI communications means that NF selection and routing must be performed in the V-PLMN **102**. In the case of any roaming request routing attempt failure, rerouting attempts may also be performed in the V-PLMN **102**, which may introduce delays in service request routing success and successful service responses to NF-C1 **116**.

[0041] Accordingly, an implementation in which model D delegated discovery is performed between V-PLMN **102** and H-PLMN **104** may be preferred. To avoid the delay in roaming service request routing due to alternate NF selection and rerouting being done in a visited V-PLMN **102**, it is proposed to have the service discovery, NF selection, reselection, routing, rerouting, or multiple of the above be performed in home network H-PLMN **104**. A V-SCP **114** may forward the Model D delegated discovery request along with NF selection parameters to the home network H-PLMN **104**, where H-SCP **120** may be deployed to support Model D 5G SBI indirect communication.

[0042] In scenarios where NFc and NFp pertain to different domains, such as different PLMNs, NPNs (non-public networks), or different regional organizations in a same PLMN, delegated discovery to a home network may provide multiple advantages. For a visited network, delegated discovery may result in faster service response times. The operator (or organization) of the target or home domain may prefer to perform the discovery and selection of the NFp in the target domain through the use of indirect communication with delegated discovery for a number of reasons. For example, delegated discovery may allow the home network to avoid disclosing information about candidate NFp that may be sensitive (e.g. load and capacity info, topology info, etc.). Delegated discovery may enable the target domain to apply consistent discovery and selection policies for requests issued from other domains, to conform with those issued within the same domain (e.g. harmonized policies for intra and inter-PLMN requests. Additionally, delegated discovery may enable the operator of the target domain to deploy its own discovery or selection policies, independently from NF implementations in other domains, including the possibility to use operator-specific attributes.

[0043] Accordingly, it may be advantageous to enable a V-PLMN **102** to determine network deployment info (e.g., Model B, C or D support) of a H-PLMN **104**, so that a V-SCP **114** or consumer NF **116** can delegate service discovery and NF selection to the H-PLMN **104** when such delegation is supported. In order to implement such a system, V-NRF **110**, V-SCP **114**, other components, or any combination thereof, may include a delegation and routing module (DRM **128**) configured to determine the capabilities of remote networks (e.g., H-PLMN **104**), and to implement the delegated discovery and routing as discussed herein.

[0044] At the bootup time of a network, or when networks are connected, V-NRF **110** (e.g., via DRM **128**) and H-NRF **122** can negotiate and discover communication models used by NFs and SCPs in their respective networks (or optionally, a one-way discovery may be performed). The negotiation may include learning about ‘Model D delegated discovery’ capability supported by both networks. In some embodiments, discovery of another network's capabilities can also be done upon a first discovery request for producer NFs (H-NFp **124** or **126**) or of H-SCP **120** by visitor consumer NFs (NV-C1 **116**) or by V-SCP **114**. The model and capability discovery results can then be cached by V-NRF **110** and H-NRF **122**. V-SCP **114** can query or subscribe to V-NRF **110** in order to learn about the model or capabilities of H-PLMN **104**.

[0045] If V-SCP **114** supports ‘Model D delegated discovery’ (e.g., if V-PLMN **102** is a model D deployment network), upon receiving a service request from NV-C1 **116** that is destined to an H-NFp, V-SCP **114** may attempt to discover, via V-NRF **110** (and H-NRF **122**), an H-SCP **120** that can also support ‘Model D delegated discovery’. In accordance with the above operations, if V-SCP **114** learns that H-SCP **120** supports ‘Model D delegated discovery’, and based on an SLA (service-level agreement) between operators of V-PLMN **102** and H-PLMN **104**, V-SCP **114** may forward discovery requests of H-NFp to H-SCP **120**. Consequently, H-SCP **120** may perform delegated discovery & selection of H-NFp based on the service request delegated from V-PLMN **102**. An example process of negotiating and discovery capabilities between networks is described in regard to FIG. **4**.

[0046] FIG. **4** is a flow diagram of an example system **400** configured to perform 5G remote PLMN capability sharing and service discovery delegation, in accordance with certain embodiments of the present disclosure. In particular, system **400** may depict an example process by which a roaming or visited network determines the deployment model or capabilities of a home network, to determine whether delegated service discovery can be performed with the home network. System **400** may include a V-PLMN **402** having a V-SCP **414**, V-NRF **410**, and V-SEPP **412**, as well as an H-PLMN **404** including an H-SEPP **418**, H-SCP **420**, and an H-NRF **422**. The components of V-PLMN **402** and H-PLMN **404** may substantially correspond to components of V-PLMN **102** and H-PLMN **104** of FIG. **1**.

[0047] When V-PLMN **402** is configured to operate with H-PLMN **404**, or when a first service request is to be communicated from V-PLMN **402** to H-PLMN **404**, a capability discovery or negotiation operation may occur. At **430**, V-NRF **410** may initiate a negotiation procedure to determine capabilities of one or more remote networks. For example, V-PLMN **402** or V-NRF **410** may be configured, such as by an operator of V-PLMN **402**, with a list of remote networks for which roaming communication is expected. The list may include PLMN Ids for each, addressing or access details, or other information. At startup, V-NRF **410** may perform the operation of system **400** with each remote network on its list, or on specific designated remote networks.

[0048] At **432**, V-NRF **410** may send a 5G SBI communication deployment model and SCP capability negotiation request to H-NRF **422** (e.g., by way of V-SEPP **412**, H-SEPP **418**, and potentially H-SCP **420**). In some examples, the request may include target PLMN Id(s) and requester PLMN Id(s), requesterNF=NRF (e.g., for V-NRF **410**), and other details. The request may be sent via a custom parameter, e.g., “GET . . . /communicationDeploymentInfo”, which the target network (H-PLMN **404**) may be configured to recognize and respond to. If the target network is not configured to respond to the request, a fail or error response may be returned. In this case, V-PLMN **402** may treat H-PLMN **404** as a network that does not support delegated discovery and routing, and may operate as described in regard to FIG. **2** or **3**.

[0049] If the H-NRF **422** is configured to recognize the capability negotiation request, it may return the 5G SBI communication deployment model (e.g., Model B, C, D) deployed in H-PLMN **404**, at **434**. H-NRF **422** may return the 5G SBI communication deployment model and SCP capability negotiation response based operator configuration at H-NRF **422**, or based on registered SCP profiles (e.g., of H-SCP **420**) and their capabilities. For example, when an H-SCP **420** registers with H-NRF **422**, it may provide its delegated routing and other capabilities. Based on the registered details, the H-NRF **422** can determine the deployment model and provide that in response to the capability negotiation request **432**, or the H-NRF **422** can merely provide capabilities without directly specifying the deployment model. V-NRF **410** may update its own database based on the deployment model or capabilities information received from H-NRF **422**, so that V-NRF **410** knows how to handle future NF service requests targeting H-PLMN **404**.

[0050] At **436**, V-NRF **410** may send a subscription request to H-NRF **422**, in order to receive notifications when the 5G SBI communication deployment model and SCP capabilities of H-PLMN **404** are changed. The subscription request may also include target remote PLMN Id(s), request PLMN Id(s), requesterNF=NRF, and other details, and may also be sent via a custom parameter; e.g.: "POST . . . /communicationDeploymentInfoSubscribe". In response to the subscription request, H-NRF **422** may create a subscription resource, and may return the subscription resource along with a **401** success response with location header, at **438**.

[0051] At **440**, V-SCP **414** may request 5G SBI communication deployment model and SCP capability information for H-PLMN **404** from V-NRF **410**, such as based on configured or selected PLMN Ids. In response, V-NRF **410** may provide the deployment model and SCP capability information for H-PLMN **404** to V-SCP **414**, at **442**, which may store the information locally for fast access in future operations. V-SCP **414** may also subscribe to V-NRF **410** to receive updates to changes to the deployment model or SCP capabilities of H-PLMN **404**, at **444**. At **446**, V-NRF **410** may create a subscription resource and provide the subscription details to V-SCP **414**.

[0052] At some point, an update to the 5G SBI communication deployment model and SCP capability of H-PLMN **404** may occur. H-PLMN **404** deployment changes may occur due to H-SCP **420** deployment changes, and its supported capabilities. In such cases, H-NRF **420** may send a notification to V-NRF **410** as per the subscription from **436**. The capability update notification may be provided to V-NRF **410** via a custom parameter, e.g., "POST . . . /{callbackUri} communicationDeploymentInfoNotification". In response, V-NRF **410** may update the deployment model and SCP capability details stored at V-NRF **410**, and may return an acknowledgement response to H-SCP **422**. Additionally, if V-SCP **414** subscribed to V-NRF **410** for updates to the capabilities of H-PLMN **404**, then V-NRF **410** may send a model and capabilities update to V-SCP **414**, at **450**. V-SCP **414** may update its local model and capabilities information for H-PLMN **404** based on the notification.

[0053] Once V-PLMN **402** has determined the deployment model or capabilities of H-PLMN **404**, and ascertained that H-PLMN supports delegated discovery and (re) routing, then NF requests may be delegated from V-PLMN **402** to H-PLMN **404**. An example process for delegated discovery and routing is described in regard to FIG. **5**.

[0054] FIG. **5** is a flow diagram of an example system **500** configured to perform 5G remote PLMN capability sharing and service discovery delegation, in accordance with certain embodiments of the present disclosure. In particular, system **500** may depict an example process for delegation of NF discovery and service request routing, from a model D V-PLMN **502** (e.g., one which supports delegation) to a model D H-PLMN **504**. System **500** may include a V-PLMN **502** having an NF-C1 **516**, V-SCP **514**, V-NRF **510**, and V-SEPP **512**, as well as an H-PLMN **504** including an H-SEPP **518**, H-SCP **520**, H-NRF **522**, NF-P1 **524**, and NF-P2 **526**. The components of V-PLMN **502** and H-PLMN **504** may substantially correspond to components of V-PLMN **102** and H-PLMN **104** of FIG. **1**.

[0055] FIG. **5** depicts an example of utilizing a system where V-PLMN **502** has obtained details on the deployment model of H-PLMN **504** (e.g., according to the process of FIG. **4**), and determined that H-PLMN **504** supports delegated discovery. NF-C1 **516** may issue a discovery request and service selection parameters to V-SCP **514**, at **530**. The service selection parameters may indicate what type of service the consumer NF is seeking, so that an appropriate producer can be determined.

[0056] If V-SCP **514** already knows the routing details to an H-SCP **520** (e.g., one that supports delegation), V-SCP **514** may proceed to H-SCP selection, at **540**. If V-SCP **514** does not already have information on H-SCP **520**, V-SCP **514** may send a discovery request to V-NRF **510** for an NF

Type=SCP that supports delegation in H-PLMN **504**, at **534**. At **536**, the V-NRF **510** may query the H-NRF **522** (e.g., via V-SEPP **512** and H-SEPP **518**) for such an SCP in H-PLMN **504**, and forward the received details on H-SCP(s) **520** to V-SCP **514**, at **538**. Based on the determined H-SCPs **520** that support delegation, V-SCP **514** may perform H-SCP selection for performing delegated discovery of an NF producer for the discovery request **530**, at **540**.

[0057] At **542**, V-SCP **514** may optionally perform OAuth 2.0 authentication and authorization of NF-C1 **516**, in roaming scenarios. When V-SCP **514** forwards delegated discovery requests to H-SCP **520**, then NF-C1 **516** authentication at V-NRF **510** may be missing. To address this, V-SCP **514** may be configured to perform authentication and authorization on NF-C1 **516**. (See, e.g. TS33.510, 13.4.1.2 and 13.4.1.2.1). V-SCP **520** may authenticate NF-C1 **516** based on an mTLS (mutual transport layer security) or CCA (client credentials assertion) header received with delegated discovery request **530** NF-C1 **516**. Based on the header information, the V-SCP **514** may ensure that NF-C1 **516** is registered with V-NRF **510**. V-SCP **514** may access V-NRF **510** to verify the registration. Alternately, V-SCP **514** may learn the NF topology of V-PLMN **502** from V-NRF **510** over one or more prior exchanges; V-SCP **514** can validate that NF-C1 **516** is registered with V-NRF **510** if NF-C1 **516** is in V-SCP **514**'s learned topology, without contacting V-NRF **510** to verify the registration.

[0058] At **544**, V-SCP **514** can provide the delegated discovery request, including the discovery and selection parameters for a producer NF, to an H-SCP **520** that supports delegation. Based on the delegated discovery request, H-SCP **520** may perform an NF discovery request and response exchange with H-NRF **522**, at **546**. The H-SCP **520** may obtain information about both NF-P1 **524** and NF-P2 **526** as potential producer NFs that may provide the requested service. At **548**, H-SCP **520** may perform NF selection for a first routing attempt, and in the depicted example may select NF-P1 **524** as the first producer NF to which to route the request.

[0059] At **550**, after producer NF selection, H-SCP **520** may optionally obtain an access token from H-NRF **522** using the discovery headers received with the delegated discovery request **544**, as part of an OAuth 2.0 authorization procedure.

[0060] At **552**, H-SCP **520** may send the request to NF-P1 **524** in a first routing attempt. H-SCP **520** may receive a response at **554**, indicating either success or failure. If the first routing attempt succeeded, the process flow may resume from **562**; otherwise, H-SCP **520** may perform NF reselection when the first routing attempt fails. NF reselection may include H-SCP **520** choosing another NF producer option from the list obtained at **546**; in the present example, for NF-P2 **526**. At **558**, H-SCP **520** may send the request to NF-P2 **526** during a second or alternate routing attempt, and receive a success response at **560**. H-SCP **520** may forward or provide a success response to V-SCP **514**, at **562**, and V-SCP **514** may forward or provide a success response to NF-C1 **516** at **564**, corresponding to the initial request from **530**.

[0061] By locally handling service discovery and routing in H-PLMN **504**, it may save time and be more efficient in obtaining successful service responses. Service discovery and message routing may also be handled internally by H-PLMN **504** and its components, thereby enabling H-PLMN **504** to maintain consistent or uniform operations and taking full advantage of any capabilities supported by the components of H-PLMN **504**. Further, this implementation may limit how much topology and other sensitive details a H-PLMN **504** must share to V-PLMN **502**, such as regarding delegation-capable SCPs **520**. In some examples, H-PLMN **504** may be configured (e.g., via H-SEPP **518**) to have an H-SEPP **518** that can perform delegated routing, or that has one or more selected H-SCPs **520** it uses for routing requests from V-PLMN **502**. This may further limit the exposure of H-PLMN **504** details to other networks, because H-PLMN **504** may only need to provide details regarding H-SEPP **518**.

[0062] The process flow of FIG. **5** may correspond to a system **500** in which V-PLMN **602** has a model D deployment or is configured to delegate NF discovery and request routing. Another example implementation in which V-PLMN has a model C deployment (without discovery delegation as a pre-configured feature) is described in regard to FIGS. **6-7**.

[0063] FIG. **6** is a flow diagram of an example system **600** configured to perform 5G remote PLMN capability sharing and service discovery delegation, in accordance with certain embodiments of the present disclosure. In particular, system **600** may depict an example process for an initial NF discovery request routing from a model C V-PLMN **602** (e.g., one which does not have default delegation support) to a model D H-PLMN **604**. System **600** may include a V-PLMN **602** having an NF-C1 **616**, V-SCP **614**, V-NRF **610**, and V-SEPP **612**, as well as an H-PLMN **604** including an H-SEPP **618**, H-SCP **620**, H-NRF **622**, NF-P1 **624**, and NF-P2 **626**. The components of V-PLMN **602** and H-PLMN **604** may substantially correspond to components of V-PLMN **102** and H-PLMN **104** of FIG. **1**.

[0064] A V-SCP **614** from a model C deployment can still delegate NF re-selection and routing to an H-SCP **620** from a model D deployment. A model C deployment V-SCP **614** may forward a 5G SBI service request with routing binding header to H-SCP **620**, whereupon H-SCP **620** can perform NF re-selection and rerouting to producer NFs based on the routing binding header. Note that for Model-C Visitor network **602** deployment, an initial resource creation service request (e.g., POST or PUT method) from NF-C1 **616** may not have routing binding header. So if V-SCP **614** forwards the same request to H-SCP **620**, then H-SCP **620** may not be able to perform NF re-selection and alternate routing, as H-SCP **620** may not have any NF reselection info (e.g., routing binding header or delegated discovery headers). Therefore, in order to perform NF re-selection and rerouting, H-SCP **620** should be provided with NF reselection information from a routing binding header or delegated discovery header.

[0065] After determining a deployment model and SCP capabilities of the remote home network (as described in regard to FIG. **4**), NF-C1 **616** may issue an initial NF discovery request for resource creation to V-SCP **614**, at **630**. V-SCP **614** may forward the discovery request to V-NRF **610**, at **632**, and V-NRF **610** may exchange an NF discovery request and response with H-NRF **622** (e.g., via V-SEPP **612**, H-SEPP **618**, and potentially H-SCP **620**), at **634**. V-NRF **610** may return the NF discovery response to V-SCP **614**, which may in turn provide the response back to NF-C1 **616**. The NF discovery response may include address information and metadata for the potential H-NF producers, such as "NF-P1: nf-p1-fqdn1.com, nf-setid: set1; NF-P2: nf-p2-fqdn2.com, nf-setid: set1".

[0066] Based on the NF discovery response and the provided NF producer options, NF-C1 **616** may perform initial NF selection, at **640**, and may select NF-P1 **624** in this example. NF-C1 **616** may then issue a model C service request to V-SCP **614** that identifies the selected NF-P, and alternate NF-P selection information, at **642**. For example, the model C service request **642** may include info "3gpp-sbi-target-apiRoot" in a header that provides the selected producer info (e.g. scheme://nf-p1-fqdn1.com.com: port/to identify NF-P1 **624**). To enable alternate NF selection and rerouting in H-PLMN **604** in the event the request to the initially selected NF-P1 **624** fails, NF-C1 **616** may include alternate NF selection info in 3gpp-sbi-discovery-* header(s); e.g., in this case 3gpp-sbi-discovery-target-nf-set-id=set1, so that H-SCP **620** can use it for alternate NF selection and rerouting later, at **652**. At **644**, V-SCP **614** may forward the request to H-SCP **620** along with NF selection info from NF-C1 **616**, according to H-PLMN **604** deployment model and capability.

[0067] H-SCP **620** may, based on the received request, make a first routing attempt to NF-P1 **624** as per the received "3gpp-sbi-target-apiRoot" header info, at **646**, and receive a success or fail response, at **648**. At **650**, if the response was successful, the process flow may continue at **660**. If the response indicated routing failure, H-SCP **620** may initiate an NF reselection operation at **650**. At **652**, NF reselection may include the H-SCP **620** issuing an NF discovery request to H-NRF **622** based on the alternate NF selection indicated in the discovery header or routing binding header info from the NF routing request received from NF-C1 **616**. For example, the NF routing request **642** metadata may indicate an NF set Id that may be used to determine an alternate NF producer from H-NRF **622**. At **654**, H-NRF **622** may provide an NF discovery response to H-SCP **620** that indicates viable NF producers to use as alternates.

[0068] Based on the NF discovery response at **654**, H-SCP **620** may perform a rerouting attempt to NF-P2 **626**, at **656**. In response, NF-P2 **626** may send a success response to H-SCP **620**. The success response may include location data for the successful NF producer resource, such as, "Location: scheme://nf-p2-fqdn2.com: port/apispecificresourceUri; 3gpp-Sbi-Binding: NF Set Id=set1". The success response, as well as the location information, may be returned from H-SCP **620** to V-SCP **614**, at **660**, and from V-SCP **614** to NF-C1 **616**, at **662**. The NF-C1 **616** may store a record of which H-NFp has the created resource corresponding to the successful routing request; in this case NF-P2 **626**. Therefore, if the initial producer NF (e.g., NF-P1 **624**) selected by NF-C1 **616** was not successful, NF-C1 **616** would know that subsequent service requests for that same resource should go to the alternate selected producer (e.g., NF-P2 **626**). Subsequent routing requests may be handled in a different manner, as described in regard to FIG. **7**.

[0069] FIG. **7** is a flow diagram of an example system **700** configured to perform 5G remote PLMN capability sharing and service discovery delegation, in accordance with certain embodiments of the present disclosure. In particular, system **700** may depict an example process for a subsequent routing request using 3gpp-sbi-target-apiroot header along with routing binding header information. The subsequent routing of system **700** may be issued from a model D V-PLMN **702**, but in the current example it will be shown from a model C V-PLMN **702** to a model D H-PLMN **704**, after initial resource creation as described in regard to system **600**. System **700** may include a V-PLMN **702** having an NF-C1 **716**, V-SCP **714**, V-NRF **710**, and V-SEPP **712**, as well as an H-PLMN **704** including an H-SEPP **718**, H-SCP **720**, H-NRF **722**, NF-P1 **724**, and NF-P2 **726**. The components of V-PLMN **702** and H-PLMN **704** may substantially correspond to components of V-PLMN **102** and H-PLMN **104** of FIG. **1**.

[0070] After resource creation from FIG. **6**, NF-C1 **716** may have binding information. Subsequent routing requests regarding the same resource from NF-C1 **716** to V-SCP **714**, at **730**, may include a routing binding header along with producer NF selection info. For example, a subsequent request for the resource created at NF-P2 **726** (as described in FIG. **7**) may include, "3gpp-sbi-target-apiRoot: scheme://nf-p2-fqdn2.com.com: port/; 3gpp-sbi-routing-binding: NF Set Id=set1". V-SCP **714** may forward the request to H-SCP **720** (e.g., via V-SEPP **712** and H-SEPP **718**) along with the NF selection information, as per the H-PLMN **704** deployment model and capability.

[0071] H-SCP **720** can perform routing or rerouting on the received 3gpp-sbi-target-apiRoot and routing binding headers; in this case, routing the request to NF-P2 **726** at **734**. H-SCP **720** may receive a response from NF-P2 **726**, at **736**. If the response indicates a success, at **738**, the process flow may continue from **748**. If the response **736** indicates a failure, H-SCP **720** may perform NF reselection, at **738**. H-SCP **720** may issue an NF discovery request to H-NRF **722**, at **740**, based on the information from the routing binding header, and receive an NF discovery response at **742**. At **744**, H-SCP **720** may perform an alternate NF selection routing attempt to NF-P1, based on the NF discovery response. H-SCP **720** may receive a success response, at **746**. The success response **746** may not include location and binding header information, which may only be included at the time of resource creation (e.g., a "201 Created" response). However, since the actual serving producer was changed, NF-C1 **716** may need to be informed. Accordingly, H-SCP **720** may be configured to add a 3gpp-Sbi-Target-apiRoot header in the response back to V-PLMN **702**. The 3gpp-Sbi-Target-apiRoot header may contain the apiRoot of the selected or changed target URI in a response sent to an HTTP client, when an SCP selected or reselected a new HTTP server to route the request and no location HTTP header is included in the HTTP response (for more info see TS29.500 section 5.2.3.2.4 3gpp-Sbi-Target-apiRoot). H-SCP **720** may send the success response, including the 3gpp-Sbi-Target-apiRoot header identifying NF-P1 **724** as the serving producer, to V-SCP **714**, at **748**, which may be forwarded from V-SCP **714** to NF-C1 **716**, at **750**. NF-C1 **716** may update its local information indicating which producer NF is servicing the resource request, from NF-P2 **726** to NF-P1 **724**. A system configured for remote network capability sharing and discovery and routing delegation is discussed further in regard to FIG. **8**.

[0072] FIG. **8** illustrates an apparatus **800** including a computing system **801** that is representative of any system or collection of systems in which the various processes, systems, programs, services, and scenarios disclosed herein may be implemented. For example, computing system **801** may be an example of UE **106**, V-PLMN **102**, H-PLMN **104**, V-NRF **110**, V-SCP **114**, V-SEPP **112**, NF-C1 **116**, DRM **128**, H-SEPP **118**, H-NRF **122**, H-SCP **120**, NF-P1 **124**, or NF-P2 of FIG. **1**. Examples of computing system **801** include, but are not limited to, desktop computers, laptop computers, server computers, routers, web servers, cloud computing platforms, and data center equipment, as well as any other type of physical or virtual server machine, physical or virtual router, container, and any variation or combination thereof.

[0073] Computing system **801** may be implemented as a single apparatus, system, or device or may be implemented in a distributed manner as multiple apparatuses, systems, or devices. Computing system **801** may include, but is not limited to, processing system **802**, storage system **803**, software **805**, communication interface system **807**, and user interface system **809**. Processing system **802** may be operatively coupled with storage system **803**, communication interface system **807**, and user interface system **809**.

[0074] Processing system **802** may load and execute software **805** from storage system **803**. Software **805** may include a 5G remote PLMN capability sharing and service discovery delegation process **806**, which may be representative of any of the operations for determining a deployment model or capabilities of a remote network, and based on the capabilities, delegate service discovery and request routing to the remote network, as discussed with respect to the preceding figures. When executed by processing system **802**, software **805** may direct processing system **802** to operate as described herein for at least the various processes, operational scenarios, and sequences discussed in the foregoing implementations. Computing system **801** may optionally include additional devices, features, or functionality not discussed for purposes of brevity.

[0075] In some embodiments, processing system **802** may comprise a micro-processor and other circuitry that retrieves and executes software **805** from storage system **803**. Processing system **802** may be implemented within a single processing device but may also be distributed across multiple processing devices or sub-systems that cooperate in executing program instructions. Examples of processing system **802** may include general purpose central processing units, graphical processing units, application specific processors, and logic devices, as well as any other type of processing device, combinations, or variations thereof.

[0076] Storage system **803** may comprise any memory device or computer readable storage media readable by processing system **802** and capable of storing software **805**. Storage system **803** may include 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. Examples of storage media include random access memory, read only memory, magnetic disks, optical disks, optical media, flash memory, virtual memory and non-virtual memory, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other suitable storage media. In no case is the computer readable storage media a propagated signal.

[0077] In addition to computer readable storage media, in some implementations storage system **803** may also include computer readable communication media over which at least some of software **805** may be communicated internally or externally. Storage system **803** may be implemented as a single storage device but may also be implemented across multiple storage devices or sub-systems co-located or distributed relative to each other. Storage system **803** may comprise additional elements, such as a controller, capable of communicating with processing system **802** or possibly other systems.

[0078] Software **805** (including 5G remote PLMN capability sharing and service discovery delegation process **806** among other functions) may be implemented in program instructions that may, when executed by processing system **802**, direct processing system **802** to operate as described with respect to the various operational scenarios, sequences, and processes illustrated herein.

[0079] In particular, the program instructions may include various components or modules that cooperate or otherwise interact to carry out the various processes and operational scenarios described herein. The various components or modules may be embodied in compiled or interpreted instructions, or in some other variation or combination of instructions. The various components or modules may be executed in a synchronous or asynchronous manner, serially or in parallel, in a single threaded environment or multi-threaded, or in accordance with any other suitable execution paradigm, variation, or combination thereof. Software **805** may include additional processes, programs, or components, such as operating system software, virtualization software, or other application software. Software **805** may also comprise firmware or some other form of machine-readable processing instructions executable by processing system **802**.

[0080] In general, software **805** may, when loaded into processing system **802** and executed, transform a suitable apparatus, system, or device (of which computing system **801** is representative) overall from a general-purpose computing system into a special-purpose computing system customized to implement the systems and processes as described herein. Indeed, encoding software **805** on storage system **803** may transform the physical structure of storage system **803**. The specific transformation of the physical structure may depend on various factors in different implementations of this description. Examples of such factors may include, but are not limited to, the technology used to implement the storage media of storage system **803** and whether the computer-storage media are characterized as primary or secondary storage, as well as other factors.

[0081] For example, if the computer readable storage media are implemented as semiconductor-based memory, software **805** may transform the physical state of the semiconductor memory when the program instructions are encoded therein, such as by transforming the state of transistors, capacitors, or other discrete circuit elements constituting the semiconductor memory. A similar transformation may occur with respect to magnetic or optical media. Other transformations of physical media are possible without departing from the scope of the present description, with the foregoing examples provided only to facilitate the present discussion.

[0082] Communication interface system **807** may include communication connections and devices that allow for communication with other computing systems (not shown) over communication networks (not shown). Examples of connections and devices that together allow for inter-system communication may include network interface cards, antennas, power amplifiers, radio-frequency (RF) circuitry, transceivers, and other communication circuitry. The connections and devices may communicate over communication media to exchange communications with other computing systems or networks of systems, such as metal, glass, air, or any other suitable communication media.

[0083] Communication between computing system **801** and other computing systems (not shown), may occur over a communication network or networks and in accordance with various communication protocols, combinations of protocols, or variations thereof. Examples include intranets, internets, the Internet, local area networks, wide area networks, wireless networks, wired networks, virtual networks, software defined networks, data center buses and backplanes, or any other type of network, combination of network, or variation thereof.

[0084] As will be appreciated by one skilled in the art, aspects of the present invention may be embodied as a system, method, computer program product, and other configurable systems. Accordingly, aspects of the present invention may take the form of an entirely hardware embodiment, an entirely software embodiment (including firmware, resident software, micro-code, etc.) or an embodiment combining software and hardware aspects that may all generally be referred to herein as a “circuit,” “module” or “system.” Furthermore, aspects of the present invention may take the form of a computer program product embodied in one or more memory devices or computer readable medium(s) having computer readable program code embodied thereon.

[0085] Unless the context clearly requires otherwise, throughout the description and the claims, the words "comprise," "comprising," "including," and the like are to be construed in an inclusive sense, as opposed to an exclusive or exhaustive sense; that is to say, in the sense of "including, but not limited to." As used herein, the terms "connected," "coupled," or any variant thereof means any connection or coupling, either direct or indirect, between two or more elements; the coupling or connection between the elements can be physical, logical, or a combination thereof. Additionally, the words "herein," "above," "below," and words of similar import, when used in this application, refer to this application as a whole and not to any particular portions of this application. Where the context permits, words in the above Detailed Description using the singular or plural number may also include the plural or singular number respectively. Except when used for the selection or determination between alternatives, the word "or" in reference to a list of two or more items covers all the following interpretations of the word: any of the items in the list, all the items in the list, and any combination of the items in the list.

[0086] The phrases "in some embodiments," "according to some embodiments," "in the embodiments shown," "in other embodiments," and the like generally mean the particular feature, structure, or characteristic following the phrase is included in at least one implementation of the present technology, and may be included in more than one implementation. In addition, such phrases do not necessarily refer to the same embodiments or different embodiments.

[0087] The above Detailed Description of examples of the technology is not intended to be exhaustive or to limit the technology to the precise form disclosed above. While specific examples for the technology are described above for illustrative purposes, various equivalent modifications are possible within the scope of the technology, as those skilled in the relevant art will recognize. For example, while processes or blocks are presented in a given order, alternative implementations may perform routines having steps, or employ systems having blocks, in a different order, and some processes or blocks may be deleted, moved, added, subdivided, combined, and/or modified to provide alternative or sub combinations. Each of these processes or blocks may be implemented in a variety of different ways. Also, while processes or blocks are at times shown as being performed in series, these processes or blocks may instead be performed or implemented in parallel, or may be performed at different times. Further any specific numbers noted herein are only examples: alternative implementations may employ differing values or ranges.

[0088] The teachings of the technology provided herein can be applied to other systems, not necessarily the system described above. The elements and acts of the various examples described above can be combined to provide further implementations of the technology. Some alternative implementations of the technology may include not only additional elements to those implementations noted above, but also may include fewer elements.

[0089] These and other changes can be made to the technology in light of the above Detailed Description. While the above description describes certain examples of the technology, and describes the best mode contemplated, no matter how detailed the above appears in text, the technology can be practiced in many ways. Details of the system may vary considerably in its specific implementation, while still being encompassed by the technology disclosed herein. As noted above, particular terminology used when describing certain features or aspects of the technology should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the technology with which that terminology is associated. In general, the terms used in the following claims should not be construed to limit the technology to the specific examples disclosed in the specification, unless the above Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the technology encompasses not only the disclosed examples, but also all equivalent ways of practicing or implementing the technology under the claims.

[0090] To reduce the number of claims, certain aspects of the technology are presented below in certain claim forms, but the applicant contemplates the various aspects of the technology in any number of claim forms. For example, while only one aspect of the technology is recited as a computer-readable medium claim, other aspects may likewise be embodied as a computer-readable medium claim, or in other forms, such as being embodied in a means-plus-function claim. Any claims intended to be treated under 35 U.S.C. § 112(f) will begin with the words “means for” but use of the term “for” in any other context is not intended to invoke treatment under 35 U.S.C. § 112(f). Accordingly, the applicant reserves the right to pursue additional claims after filing this application to pursue such additional claim forms, in either this application or in a continuing application.

Claims

1. A public land mobile network (PLMN) system, comprising: one or more processors; and a memory having stored thereon instructions that, upon execution by the one or more processors, cause the one or more processors to delegate discovery and routing from a first PLMN to a second PLMN, including: send, via a first PLMN, a request for capability details of a second PLMN, the capability details including an ability of the second PLMN to handle delegated service discovery and selection; receive, at the first PLMN, the capability details; send, from the first PLMN to the second PLMN based on the capability details, a delegated discovery and network function (NF) selection request directing a remote service communications proxy (SCP) of the second PLMN to determine a producer NF of the second PLMN to process a service request from a consumer NF of the first PLMN; and receive a service request response at the first PLMN from the second PLMN in response to the delegated discovery and NF selection request.
2. The PLMN system of claim 1, wherein the instructions, upon execution by the one or more processors, further cause the one or more processors to: send the request for capability details via a local network repository function (NRF) of the first PLMN to a remote NRF of the second PLMN; and receive the capability details at the local NRF from the remote NRF.
3. The PLMN system of claim 2, wherein the instructions, upon execution by the one or more processors, further cause the one or more processors to: send the request for capability details via a GET request for a custom parameter; and send a subscription request, from the local NRF to the remote NRF, to receive an update when the capability details of the second PLMN change.
4. The PLMN system of claim 2, wherein the instructions, upon execution by the one or more processors, further cause the one or more processors to: provide the capability details from the local NRF to a local SCP of the first PLMN in response to a remote PLMN capability request from the local SCP.
5. The PLMN system of claim 4, wherein the instructions, upon execution by the one or more processors, further cause the one or more processors to: receive the service request at the local SCP from the consumer NF; and send the delegated discovery and NF selection request from the local SCP to the remote SCP in response to the service request.
6. The PLMN system of claim 5, wherein the instructions, upon execution by the one or more processors, further cause the one or more processors to: send a first NF discovery request from the local NRF to the remote NRF to determine the remote SCP; and send the delegated discovery and NF selection request to the remote SCP based on a response to the first NF discovery request received from the remote NRF.
7. The PLMN system of claim 6, further comprising: the delegated discovery and NF selection request directs the remote SCP to determine the producer NF of the second PLMN to process a service request, including: issue a second NF discovery request to the remote NRF to determine a plurality of producer NFs of the second PLMN configured to process the service request; perform a selection of the producer NF from the plurality of producer NFs; perform a first routing attempt of the service request to the producer NF; when the first routing attempt fails, perform an alternate

routing attempt to an alternate producer NF from the plurality of producer NFs; receive the service request response from a successful one of the first routing attempt and the alternate routing attempt; and forward the service request response to the local SCP.

8. The PLMN system of claim 7, further comprising: the first PLMN has a model D deployment, the model D deployment indicating a mobile network including an SCP configured to perform delegated discovery and routing; and the second PLMN has a model D deployment.

9. The PLMN system of claim 5, further comprising: the first PLMN has a model C deployment indicating a mobile network not configured to perform delegated discovery and routing; the second PLMN has a model D deployment indicating a mobile network including an SCP configured to perform delegated discovery and routing; wherein the instructions, upon execution by the one or more processors, further cause the one or more processors to perform an initial service request routing operation, including: receive a first NF discovery request from the consumer NF at the local NRF for information on the producer NF to process the service request; perform NF discovery between the local NRF to the remote NRF for a plurality of producer NFs configured to process the service request; provide a discovery response to the consumer NF including details on the plurality of producer NFS; receive an NF routing request from the consumer NF at the local SCP, the NF routing request including a discovery header identifying the producer NF as a target NF of the NF routing request; forward the NF routing request from the local SCP to the remote SCP, directing the remote SCP to: make a first routing attempt to the producer NF; when the first routing attempt fails: perform an NF discovery to the remote NRF based on the discovery header; perform an alternate routing attempt to an alternate producer NF from the plurality of producer NFs based on the NF discovery; return a success response to the first PLMN, the success response including a location identifier of the alternate producer NF; and store, at the consumer NF, the location identifier.

10. The PLMN system of claim 9, wherein the instructions, upon execution by the one or more processors, further cause the one or more processors to perform a subsequent service request routing operation, including: receive a subsequent NF routing request from the consumer NF at the local SCP, the subsequent NF routing request including a routing binding header identifying the alternate producer NF as the target NF of the subsequent NF routing request based on the location identifier; forward the subsequent NF routing request from the local SCP to the remote SCP, directing the remote SCP to: make a first subsequent routing attempt to the alternate producer NF; when the first subsequent routing attempt fails: perform a second NF discovery to the remote NRF based on the routing binding header; perform a subsequent alternate routing attempt to the producer NF based on the NF discovery; and return a subsequent success response to the first PLMN, the subsequent success response identifying the producer NF as servicing the subsequent NF routing request.

11. A method comprising: operating a first public land mobile network (PLMN) to perform delegated discovery and routing to a second PLMN, comprising: sending, via the first PLMN, a request for capability details of the second PLMN, the capability details including an ability of the second PLMN to handle delegated service discovery and selection; receiving, at the first PLMN, the capability details; sending, from the first PLMN to the second PLMN based on the capability details, a delegated discovery and network function (NF) selection request directing a remote service communications proxy (SCP) of the second PLMN to determine a producer NF of the second PLMN to process a service request from a consumer NF of the first PLMN; and receiving a service request response at the first PLMN from the second PLMN in response to the delegated discovery and NF selection request.

12. The method of claim 11, further comprising: the first PLMN has a model D deployment, the model D deployment indicating a mobile network including an SCP configured to perform delegated discovery and routing; and the second PLMN has a model D deployment.

13. The method of claim 11, further comprising: sending the request for capability details via a local network repository function (NRF) of the first PLMN to a remote NRF of the second PLMN;

and receiving the capability details at the local NRF from the remote NRF.

14. The method of claim 13, further comprising: sending the request for capability details via a GET request for a custom parameter; and sending a subscription request, from the local NRF to the remote NRF, to receive an update when the capability details of the second PLMN change.

15. The method of claim 13, further comprising: providing the capability details from the local NRF to a local SCP of the first PLMN in response to a remote PLMN capability request from the local SCP.

16. The method of claim 13, further comprising: receiving the service request at a local SCP of the first PLMN from the consumer NF; and sending the delegated discovery and NF selection request from the local SCP to the remote SCP in response to the service request.

17. The method of claim 13, further comprising: sending a first NF discovery request from the local NRF to the remote NRF to determine the remote SCP; and sending the delegated discovery and NF selection request to the remote SCP based on a response to the first NF discovery request received from the remote NRF.

18. The method of claim 17, further comprising: the delegated discovery and NF selection request directs the remote SCP to determine the producer NF of the second PLMN to process a service request, including: issuing a second NF discovery request to the remote NRF to determine a plurality of producer NFs of the second PLMN configured to process the service request; performing a selection of the producer NF from the plurality of producer NFS; performing a first routing attempt of the service request to the producer NF; when the first routing attempt fails, performing an alternate routing attempt to an alternate producer NF from the plurality of producer NFs; receiving the service request response from a successful one of the first routing attempt and the alternate routing attempt; and forwarding the service request response to a local SCP of the first PLMN.

19. The method of claim 13, further comprising: the first PLMN has a model C deployment indicating a mobile network not configured to perform delegated discovery and routing; the second PLMN has a model D deployment indicating a mobile network including an SCP configured to perform delegated discovery and routing; performing an initial service request routing operation, including: receiving a first NF discovery request from the consumer NF at the local NRF for information on the producer NF to process the service request; performing NF discovery between the local NRF to the remote NRF for a plurality of producer NFs configured to process the service request; providing a discovery response to the consumer NF including details on the plurality of producer NFs; receiving an NF routing request from the consumer NF at a local SCP of the first PLMN, the NF routing request including a discovery header identifying the producer NF as a target NF of the NF routing request; forwarding the NF routing request from the local SCP to the remote SCP, directing the remote SCP to: making a first routing attempt to the producer NF; when the first routing attempt fails: performing an NF discovery to the remote NRF based on the discovery header; performing an alternate routing attempt to an alternate producer NF from the plurality of producer NFs based on the NF discovery; returning a success response to the first PLMN, the success response including a location identifier of the alternate producer NF; and storing, at the consumer NF, the location identifier.

20. The method of claim 19, further comprising: performing a subsequent service request routing operation, including: receiving a subsequent NF routing request from the consumer NF at the local SCP, the subsequent NF routing request including a routing binding header identifying the alternate producer NF as the target NF of the subsequent service request based on the location identifier; forwarding the subsequent NF routing request from the local SCP to the remote SCP, directing the remote SCP to: making a first subsequent routing attempt to the alternate producer NF; when the first subsequent routing attempt fails: performing a second NF discovery to the remote NRF based on the routing binding header; performing a subsequent alternate routing attempt to the producer NF based on the NF discovery; and returning a subsequent success response to the first PLMN, the subsequent success response identifying the producer NF as servicing the subsequent NF routing request.