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Public Land Mobile Network Selection During International Roaming

Abstract:

This publication describes techniques and apparatuses directed to Public Land Mobile Network (PLMN) selection during international roaming. In aspects, roaming activity data is collected and compiled into a database of roaming activity data of Home PLMNs and associated Roaming PLMNs. The Roaming PLMNs are Visited PLMNs operated by a roaming partner that a subscriber's operator has a roaming agreement with. An Optimized Preferred PLMN List (OPPL) is created from the compiled roaming activity data and the OPPL is stored on user equipment (UE). During international roaming, the UE can utilize the OPPL to determine a suitable PLMN for which to attempt registration, thereby avoiding the time and resources spent attempting to register to a randomly selected neighboring PLMN.

Keywords:

Public Land Mobile Network (PLMN), roaming, foreign, international, network selection, network failure, location update procedure, location registration (LR), database, mobile country code (MCC)

Background:

A core network operator provides telecommunication services (*e.g.*, voice and data services) to user equipment (UE) through a communication network. One example of a communication network is a Public Land Mobile Network (PLMN) that includes the core network and one or more base stations, which collectively form a radio access network (RAN) connected to the network.

A PLMN has a geographical coverage area in which the base station(s) provide voice and data services to mobile subscribers. Subscribers are identified and authenticated on UE using a subscriber identification module (SIM)/universal subscriber identification module (USIM) card. A SIM/USIM card includes an International Mobile Subscriber Identity (IMSI) number and its related key. The IMSI number uniquely identifies every subscriber of a cellular network. The IMSI number includes the Mobile Country Code (MCC) (which indicates a country where the network is located), Mobile Network Code (MNC) (which identifies a network within a country), and a mobile subscription identification number (MSIN). Together, the MCC and MNC form a globally unique Home Network Identity (HNI). The HNI number identifies the subscriber's home network or "Home PLMN" (HPLMN). The network may also provide the UE with a list of PLMNs that are "equivalent" to the home PLMN (Equivalent PLMN (EHPLMN)).

In the geographical coverage area of the subscriber's HPLMN or EHPLMN, when the UE is switched on or recovers from a lack of coverage, the UE performs a PLMN selection process. In a PLMN selection process, the UE selects a PLMN (the "Selected PLMN"), searches for a suitable cell of the Selected PLMN, chooses that cell to provide available services to the UE, and monitors its control channel (aka "camps on the cell"). The UE then registers its presence in the tracking area of the chosen cell of the Selected PLMN by performing a Location Update Procedure. As an outcome of successful location registration, the Selected PLMN then becomes a "Registered" PLMN (RPLMN).

When a UE subscriber travels abroad, while searching for cellular network in a foreign country, it is critical for the UE to acquire cellular service quickly. Outside of the geographical coverage area of the subscriber's HPLMN/EHPLMN, a subscriber may utilize a process called "roaming" or "international roaming" to automatically make and receive voice calls, send and

receive data, or access other services, including home data services, by means of using a Visited PLMN of another country. A Visited PLMN is a PLMN different than the HPLMN or EHPLMN. International roaming coverage may be available through the Visited PLMN if the subscriber's operator has a roaming agreement with a roaming partner (*e.g.*, a foreign operator) in the foreign country that allows the operator's subscribers to utilize the cellular network of the roaming partner.

In generic smartphone design, once the subscriber turns off flight mode (*e.g.*, airplane mode, offline mode, standalone mode) or powers on the UE in a foreign country (international roaming), or upon the UE recovering from a lack of coverage when in international roaming, the UE begins an automatic network selection mode procedure to attempt to connect to a PLMN. The current 3rd Generation Partnership Project (3GPP) specification (*e.g.*, 3GPP TS 23.122), for the roaming network selection process, defines a User Controlled PLMN (UPLMN) list of PLMN associated with a radio access technology (RAT) (*e.g.*, LTE, GSM, WCDMA) set by the subscriber and an Operator Controlled PLMN (OPLMN) list of PLMN associated with a RAT set by the Operator. The UPLMN and OPLMN lists are stored in an elementary file on the SIM/USIM card (SIM EF) of the UE and provide a guideline for the UE to select a Visited PLMN when in a roaming situation.

There are a number of drawbacks to how international roaming PLMN selection is implemented in the current 3GPP specification. The first drawback is that when a UE in an idle mode is switched on, PLMN selection is triggered according to an ordered list of prioritized PLMNs, following an automatic network selection mode procedure, as defined in 3GPP TS 23.122 at 4.4.3.1 and 4.4.3.1.1. Following such an ordered list of prioritized PLMNs in international roaming, the UE should first search for a Registered PLMN/Equivalent PLMN, and finding none, should then search for a Home PLMN/Equivalent Home PLMN. In an international roaming

scenario, it is unlikely that the UE will find either a Registered PLMN/Equivalent PLMN or a Home PLMN/Equivalent Home PLMN, in that the MCC of the neighboring PLMNs will always be different than the MCC of the RPLMN/EPLMN/HPLMN/EHPLMN. Thus, scanning for Registered PLMN/Equivalent PLMN and Home PLMN/Equivalent Home PLMN is typically a waste of resources and battery power in an international roaming scenario.

Then, continuing to follow the list of prioritized PLMNs, the UE should then search for a PLMN defined on a UPLMN list. The UPLMN list is defined on SIM EF to provide guidance for the UE to select a Visited PLMN in a roaming situation. To make a UPLMN list workable in such a situation, the operating system of the UE would need to provide a corresponding user interface for the subscriber to manually edit SIM/USIM parameters (e.g., *EF_PLMNwACT* (EF User Controlled PLMN with Access Technology) – a list of PLMN and Access Technology pairs)) on the SIM/USIM card. Almost no smartphone manufacturer provides subscribers with access to a UPLMN editor. As a result, it is highly unlikely that the UPLMN list will define a suitable PLMN.

Continuing to further follow the list of prioritized PLMNs, the UE should then search for a PLMN defined on an OPLMN list. The OPLMN list is defined on the SIM EF to provide guidance for the UE to select a Visited PLMN in a roaming situation. To make the OPLMN list workable in such a situation, while some operators frequently update OPLMN lists stored on the SIM/USIM through over-the-air (OTA) updates to enhance roaming experience in some major countries, not every operator configures the PLMN list of roaming partners on the commercial SIM/USIM cards. Further, only major countries are typically taken into consideration during an OTA update. In a worst-case scenario, the OPLMN list on the operator SIM/USIM is empty.

Continuing to follow the list of prioritized PLMNs, in such a situation where a Registered PLMN/Equivalent PLMN cannot be found, where a Home PLMN/Equivalent Home PLMN

cannot be found, where there is no UPLMN list defined, and where the operator did not provide an OPLMN list of roaming partners, the UE should then search “other PLMN/access technology combinations” where the UE is located (*e.g.*, “neighboring PLMNs”) in a random order. As a result, the UE has no option but to randomly select a neighboring PLMN and start a cell selection process to determine if the neighboring PLMN permits registration of the UE. In such a situation, the UE selects a suitable cell of the neighboring PLMN, camps on the cell, initiates a Location Update Procedure, and sends a Location Registration (LR) request to register on the neighboring PLMN.

Randomly selecting and attempting to register on a randomly selected neighboring PLMN in an international roaming situation can waste a considerable amount of time, in that registration on the neighboring PLMN may fail (LR failure). For example, the foreign operator may determine that roaming is not allowed for the UE and the neighboring PLMN may refuse registration, listing a cause value (cause code, failure code) of #17 (Network Failure). The UE may receive multiple such registration failures before selecting and registering on a neighboring PLMN operated by a foreign operator that is a roaming partner with the subscriber’s operator.

Additionally, some types of registration rejections take longer than others to resolve, for instance, upon receipt of a cause value #17 (Network failure - causes related to PLMN specific network failures and congestion, authentication failures), the UE should wait for fifteen (15) seconds before resending another LR request to the neighboring PLMN and four (4) LR attempts may be made before the UE determines that registration on the neighboring PLMN is not allowed, potentially resulting in a delay of sixty (60) seconds in attempting to register on a wrong PLMN. The drawbacks mentioned above deeply impact the scan time to acquire service while traveling in a foreign country.

Therefore, it is desirable to provide techniques and apparatuses directed to PLMN selection during international roaming that speed up the time required to select a Visited PLMN.

Description:

This publication describes techniques and apparatuses directed to methods of PLMN selection during international roaming.

A user equipment (UE), such as a smartphone, includes at least one processor, at least one transceiver, and computer-readable storage media (CRM). The UE may be SIM-based/USIM-based. In aspects, the CRM has stored thereon instructions that responsive to execution by the processor, cause the processor to execute methods described herein. The CRM may include any suitable memory or storage device (*e.g.*, storage media) such as random-access memory (RAM), static RAM (SRAM), dynamic RAM (DRAM), non-volatile RAM (NVRAM), read-only memory (ROM), SIM/USIM card, or Flash memory useable to store device data of the UE. The device data includes at least one of system information, PLMN lists, an Optimized Preferred PLMN List (OPPL), user data, multimedia data, applications, or an operating system of the UE, which are usable and/or executable by the processor(s). The device data includes executable instructions of a PLMN List Manager application that can be executed by the processor(s). The PLMN List Manager application represents functionality that causes the UE to perform operations described within this document.

In aspects, roaming activity data is collected. For example, roaming activity data may be collected by a cellular operator, by an original device manufacturer, an operating software provider, and the like. The UE may be tasked with the collection of roaming activity data. Roaming activity data may include information related to one or more of: attempts to perform

roaming PLMN selection, roaming PLMN selection failures, reject cause codes, mobile device service states (*e.g.*, what network services are available), cell identifiers (*e.g.*, a PLMN ID associated with a base station, information regarding the HPLMN and/or EHPLMN of the UE, information regarding Visited PLMN), device identifiers (*e.g.*, an universally unique identifier associated with a UE), radio access technology (*e.g.*, GSM, WCDMA, TDS-CDMA, LTE, 5G), geolocation data (*e.g.*, global navigation satellite system data associated with UE, geolocation data associated with a base station), MCC information (*e.g.*, UE MCC, PLMN MCC), hardware support bands (*e.g.*, LTE bands), frequency, timestamps).

This roaming activity data is compiled into a database of Visited PLMN operated by a roaming partner (foreign operator) that the subscriber's operator has a roaming agreement with that allows the operator's subscribers to utilize the cellular network of the roaming partner ("Roaming PLMN") and associated Home PLMN. An Optimized Preferred PLMN List (OPPL) is created from the information in the database, the OPPL including roaming pairs of Home PLMN and associated Roaming PLMN. A copy of the OPPL is stored on storage media of the UE, for example, an original device manufacturer or operating system provider can preconfigure the UE through use of an OPPL stored in SIM-based UE non-volatile memory (*e.g.*, a SIM/USIM card).

Once the subscriber turns off flight mode (*e.g.*, airplane mode, offline mode, standalone mode) or powers on the UE in a foreign country (international roaming), or upon the UE recovering from a lack of coverage when in international roaming, the UE begins a network selection mode procedure to attempt to connect to a PLMN. In the network selection mode procedure, if available, the UE selects an available Registered PLMN or Equivalent PLMN. If none are available, then the UE selects a Home PLMN or Equivalent Home PLMN, if available.

If none are available, then a PLMN List Manager Application of the UE determines the MCC of a neighboring PLMN near the UE and compares the MCC of the Roaming PLMN on the OPPL to the MCC of the neighboring PLMN to determine whether both MCCs belong to a single country. For example, the UE could determine that the MCC of a neighboring PLMN is “228” (Switzerland) and could determine if the Roaming PLMN on the OPPL also has an MCC of 228.

If the PLMN List Manager Application determines that the MCC of the Roaming PLMN and the MCC of the neighboring PLMN belong to different countries, then the UE checks the UPLMN list and the OPLMN list stored on the device to determine if either list includes a PLMN with an MCC in the current country. If at least one of the UPLMN or OPLMN lists include a PLMN with an MCC in the current country, then the UE selects that PLMN. If neither of the UPLMN or OPLMN lists include any PLMN with an MCC in the current country, then the UE should first acquire the PLMN from the OPPL which has the same MCC as the surrounding one, and the UE attempts to connect to that PLMN. If the OPPL does not contain any PLMN with an MCC in the current country, only then does the UE search “other PLMN/access technology combinations” where the UE is located (*e.g.*, “neighboring PLMNs”) in a random order, attempting to register to any PLMN that will permit registration.

The described techniques and apparatuses deliver a way to prevent the unnecessary scan for Roaming PLMN and reduces the need for one-by-one attempts to register on a random neighboring PLMN.

In aspects, the OPPL not only provides the preferred PLMN list but also provides operator band information associated to the preferred PLMN, since the scan for various bands is a critical path in PLMN selection procedure. For example, in the U.S., a carrier could limit the LTE band

to bands 2, 4, 12, 66, and 71. By limiting the number of bands searched according to country support bands, the impact of LR failure in international roaming is further limited.

A first method 100 is illustrated in FIG. 1. At a first step 102, roaming activity data is collected. At a second step 104, a database of Home PLMN and associated Roaming PLMN is compiled and a list is generated. In a third step 106, the list is stored on a UE.

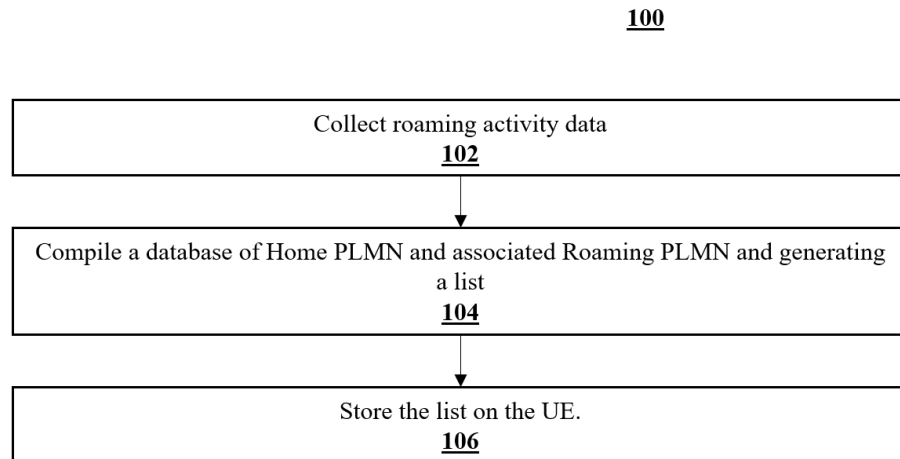
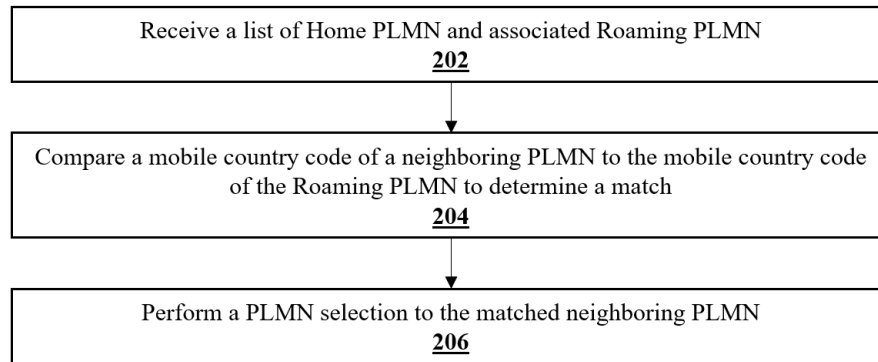


FIG. 1

A second method 200 is illustrated in FIG. 2. In a first step 202, a list of Home PLMN and associated Roaming PLMN are received. In a second step 204, the mobile country code of a neighboring PLMN is compared to the mobile country code of a Roaming PLMN on the list to determine a match. In a third step 206, PLMN selection to the matched neighboring PLMN is performed.

200**FIG. 2**

Throughout this disclosure, examples are described where a computing system (*e.g.*, the UE, a client device, a server device, a computer, or another type of computing system) may collect and analyze roaming activity data (*e.g.*, PLMN usage, device identifiers, geolocation data, time information) associated with a user. Further to the descriptions above, a user may be provided with controls allowing the user to make an election as to both if and when systems, programs, and/or features described herein may enable collection of such information and if the user is sent content or communications from a server. The computing system can be configured to only use the information after the computing system receives explicit permission from the user of the computing system to use the data. For example, in situations where the UE uses a user's current location to determine potentially available Roaming PLMN, individual users may be provided with an opportunity to provide input to control whether programs or features of the UE can collect and make use of the user's location data. Further, individual users may have constant control over what programs can or cannot do with the information. In addition, information collected may be pre-treated in one or more ways before it is transferred, stored, or otherwise used, so that personally-identifiable information is removed. For example, before the UE shares geolocation

data with another device (*e.g.*, to compile the database of roaming PLMN), the UE may pre-treat the geolocation data to ensure that any user-identifying information or device-identifying information embedded in the data is removed. Thus, the user may have control over whether information is collected about the user and the user's device, and how such information, if collected, may be used by the computing device and/or a remote computing system.

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