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Adaptive First Radio Access Technology Selection For Public Land Mobile Network Search

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ADAPTIVE FIRST RADIO ACCESS TECHNOLOGY SELECTION FOR PUBLIC LAND MOBILE NETWORK SEARCH

Abstract

A user equipment (UE) device in a wireless communication network adaptively selects a first Radio Access Technology (RAT) to initially perform a Public Land Mobile Network (PLMN) search for a given Mobile Network Operator (MNO). The adaptive RAT selection performed by the UE device is based on one or more sets of RAT selection criteria, such as frequency band readiness, UE device location, RAT deployment time frames, network configurations, and so on. In addition, the UE device implements adaptive RAT preference lists associated with the different RAT selection criteria. Each of the adaptive RAT preference lists indicates a RAT selection order to be followed by the UE device depending on, for example, the current RAT selection criteria being implemented by the UE device.

Background

Modern wireless UE devices, such as cellular phones, can communicate over multiple frequency bands and RATs. Examples of RATs include Fifth Generation (5G) New Radio (NR), Evolved Universal Terrestrial Radio Access (E-UTRA), also referred to as Long Term Evolution (LTE) or LTE-Advanced (LTE-A), Universal Mobile Telecommunications System (UMTS), Global System for Mobile communication (GSM), and so on. The specification of each RAT includes a set of operating radio frequency (RF) bands. UE devices typically support a process of searching their supported operating bands to select a suitable PLMN on which to operate. Such a process is referred to as PLMN search and is performed, for example, at power-on, after return from out-of-service (OOS) conditions, during roaming, and so on.

As part of the PLMN search process, the UE device typically searches for a PLMN according to a RAT preference list, which is preconfigured either by the MNO or by the UE with some fixed default preference. For example, upon power-on or recovering from OOS, the UE device searches for its last registered PLMN or home PLMN by searching all frequency bands of each RAT supported by the UE in a fixed order (e.g., 5G NR frequency bands, then LTE frequency bands, then UMTS frequency bands, and finally the GSM frequency bands). In some instances, the UE device needs to scan each frequency band of each RAT before identifying a PLMN, which can be time and resource consuming. Also, due to different radio properties, the MNO may deploy different RAT bands at different times to achieve various business or deployment goals. For example, although an MNO may implement multiple frequency bands for a given RAT, such as 5G Stand Alone (5GSA), the MNO may initially enable only a subset of the frequency bands for the RAT. Also, in some geographical locations, the MNO may proactively redirect UE devices from a first RAT (e.g., 5GSA) to a second RAT (e.g., LTE) on a given frequency band. As such, if a UE device applies a general fixed RAT selection policy during a PLMN search, the UE device may needlessly scan frequency bands for a given RAT(s) or prioritize RATs that are not initially available, which wastes resources and provides a poor user experience.

In some configurations, a UE device implements one or more registries to control the RAT search/selection order to overcome the issues described above. For example, this registry control feature allows different MNOs to specify which RAT the UE is to select first during a PLMN search. However, although each MNO can implement its own first RAT selection, this configuration does not consider the readiness of different frequency bands within the same MNO. As described above, although multiple frequency bands may be available for a given

RAT of the MNO, the MNO may not have enabled all the frequency bands of the RAT or may have implemented the frequency bands differently throughout the network. As such, applying the same fixed RAT order within the same MNO may introduce unnecessary time gaps when trying to camp on and attach to a given PLMN.

Description

As described in detail below, a UE device implements an adaptive first RAT selection technique when searching for a given PLMN. By adaptively selecting the first RAT for initially performing the PLMN search, the UE device is able to mitigate unnecessary frequency scanning, thereby reducing unnecessary time gaps when trying to camp on and attach to a PLMN. In at least some configurations, the UE device maintains one or more adaptive RAT preference lists associated with each of the different RAT selection criteria, one or more PLMNs, one or more MNOs, a combination thereof, and so on. The UE device implements at least one of the RAT preference lists based on the criteria being considered by the UE device. For example, if the UE device is configured to select a first RAT for a PLMN search based on frequency bands, the UE device implements/selects a RAT preference list configured based on the frequency band criteria. However, if the UE device is configured to select the first RAT for a PLMN search based on its location, the UE device implements/selects a RAT preference list configured based on the UE location criteria. In at least some configurations, an adaptive RAT preference list(s) indicates multiple first RATs that are selectable by the UE device based on which criterion/criteria is satisfied or not satisfied in the set of different criteria being considered by the UE device. The adaptive RAT preference list(s) can be configured and updated by the MNO, the UE device, and so on.

FIG. 1 below illustrates an example method for performing an adaptive first RAT selection technique during a PLMN search. In this example method, when the UE device powers on, recovers from an OOS condition, or performs some other operation, the UE device initiates a search for its last registered PLMN or its home PLMN. The UE device then adaptively selects a supported first RAT to initially perform the PLMN search based on a set of first RAT selection criteria. For example, the UE device adaptively selects a first RAT based on frequency band (MNO readiness) criteria in one configuration. In this configuration, if the UE device is operating in a first frequency band (e.g., n41), the UE device selects a given first RAT (e.g., NR) for initially performing the PLMN search. However, if the UE device is operating in a second frequency band (e.g., n71), the UE device selects a different first RAT (e.g., LTE) to perform the PLMN search. If the UE device is not operating in any of the bands of interest (e.g., n41 or n71), the UE, in some configurations, selects a default first RAT. Also, the first RAT selected by the UE device can be on a per MNO basis. For example, a first MNO can configure the UE device to select an NR RAT for initially performing a PLMN search based on the UE device operating in a first frequency band. In contrast, a second MNO can configure the UE device to select an LTE RAT for initially performing the PLMN search based on the UE device operating in the same frequency band.

In at least some configurations, the UE device determines the specific first RAT and subsequent RATs to select for a given frequency band from information provided in one or more of the adaptive RAT preference lists maintained by the UE device. For example, an adaptive RAT preference list can indicate that if the UE device is operating in the first frequency band (e.g., n41), the UE device is first to select the NR RAT, then the LTE RAT, the UMTS RAT, and finally the GSM RAT. The adaptive RAT preference list can further indicate that if the UE

device is operating in the second frequency band (e.g., n71), the UE device is first to select the LTE RAT, then the NR RAT, the UMTS RAT, and finally the GSM RAT.

In another configuration, the UE device adaptively selects the first RAT based UE location criteria. For example, if the UE device determines that it is at or within a given distance from a first location, the UE device selects a given first RAT (e.g., NR) for initially performing the PLMN search. However, if the UE device determines that it is at or within a given distance from a second location, the UE device selects a different first RAT (e.g., LTE) for initially performing the PLMN search. In at least some instances, different MNOs can implement different UE location criteria. The UE device, in at least some configurations, determines the specific first RAT and subsequent RATs to select for a time frame from information provided in one or more of the adaptive RAT preference lists maintained by the UE device. For example, an adaptive RAT preference list can indicate the UE device first selects the NR RAT for a first time frame, then selects the LTE RAT, the UMTS RAT, and finally the GSM RAT. The adaptive RAT preference list can further indicate that the UE device first selects the LTE RAT for a second time frame, then selects the NR RAT, the UMTS RAT, and finally the GSM RAT.

In a further configuration, the UE device adaptively selects a first RAT based on time frame criteria, such as when different frequency bands are to be deployed by an MNO. For example, if the UE device determines that the current date/time satisfies a first time frame threshold (e.g., within three months of Date/Time_A), the UE device selects a given first RAT (e.g., LTE) for initially performing the PLMN search. However, if the UE device determines that the current date/time fails to satisfy the first time frame threshold or satisfies a second time frame threshold (e.g., after three months from Date/Time_A), the UE device selects a different RAT (e.g., NR) to perform the PLMN search first. In at least some instances, different MNOs can implement

different time frame criteria. The UE device, in at least some configurations, determines the specific first RAT and subsequent RATs to select for a given UE location from information provided in one or more of the adaptive RAT preference lists maintained by the UE device. For example, an adaptive RAT preference list can indicate the UE device first selects the NR RAT for a first UE location, then selects the LTE RAT, the UMTS RAT, and finally the GSM RAT. The adaptive RAT preference list can further indicate the UE device selects the LTE RAT first for a second UE location, then selects the NR RAT, the UMTS RAT, and finally the GSM RAT.

In yet another configuration, the UE device adaptively selects a first RAT based on network configuration criteria. In this configuration, the criteria for the frequency bands are based on dynamic scanning/sampling of the network by the UE device. The UE device can dynamically infer the MNO's preferred network deployment using System Information Block (SIB) information received from the network. For example, in a 5GSA network, if the UE device receives an SIB (e.g., SIB 5) carrying the neighboring LTE cell information with cell reselection priorities, the UE device infers whether the current 5G cell has a higher or lower preference than LTE cells from the received SIB information. If the UE device determines that the current 5G cell has a higher preference over the LTE cells, the UE device selects the NR RAT for initially performing the PLMN search. Otherwise, the UE device selects the LTE RAT for initially performing the PLMN search. In an LTE network example, the LTE SIB 24 may or may not be broadcast by the network. When the UE device determines that an LTE SIB 24 has been received, the UE device determines that the network prefers the UE device to camp on the 5GSA network. As such, the UE device first selects the NR RAT to perform the PLMN search. However, if the UE device determines that an LTE SIB 24 has not been received, the UE device

determines that the network prefers the UE device to camp on the LTE network and the UE device first selects the LTE RAT to perform the PLMN search.

The UE device, in at least some configurations, determines the specific first RAT and subsequent RATs to select for a given network configuration from information provided in one or more of the adaptive RAT preference lists maintained by the UE device. For example, an adaptive RAT preference list can indicate that the UE device first selects the NR RAT for a first network configuration, then selects the LTE RAT, the UMTS RAT, and finally the GSM RAT. The adaptive RAT preference list can further indicate that the UE device first selects the LTE RAT for a second network configuration, then selects the NR RAT, the UMTS RAT, and finally the GSM RAT.

After the UE device has selected the first RAT to perform the search for the last registered PLMN or home PLMN, the UE performs a stored frequency band search starting with the first RAT selected by the UE device followed by one or more other RATs in the order specified in the adaptive RAT preference list implemented by the UE device. During the stored frequency band search for each RAT, the UE device determines if the PLMN was found. If so, the UE device attempts to attach to the network. Otherwise, the UE device performs a full frequency band search starting with the first RAT selected by the UE device followed by one or more other RATs in the order specified in the adaptive RAT preference list implemented by the UE device. During the full frequency search for each RAT, the UE device determines if the PLMN was found. If so, the UE device attempts to attach to the network. Otherwise, the UE device performs the full frequency band search for all available PLMNs. During the full frequency band search for all available PLMNs, the UE device attempts to attach to a PLMN when detected. If the attach procedure is unsuccessful, the UE device remains on limited services and

determines if any PLMNs remain to be searched. If so, the UE device proceeds to search for the remaining PLMNs. Otherwise, the UE remains on limited services.

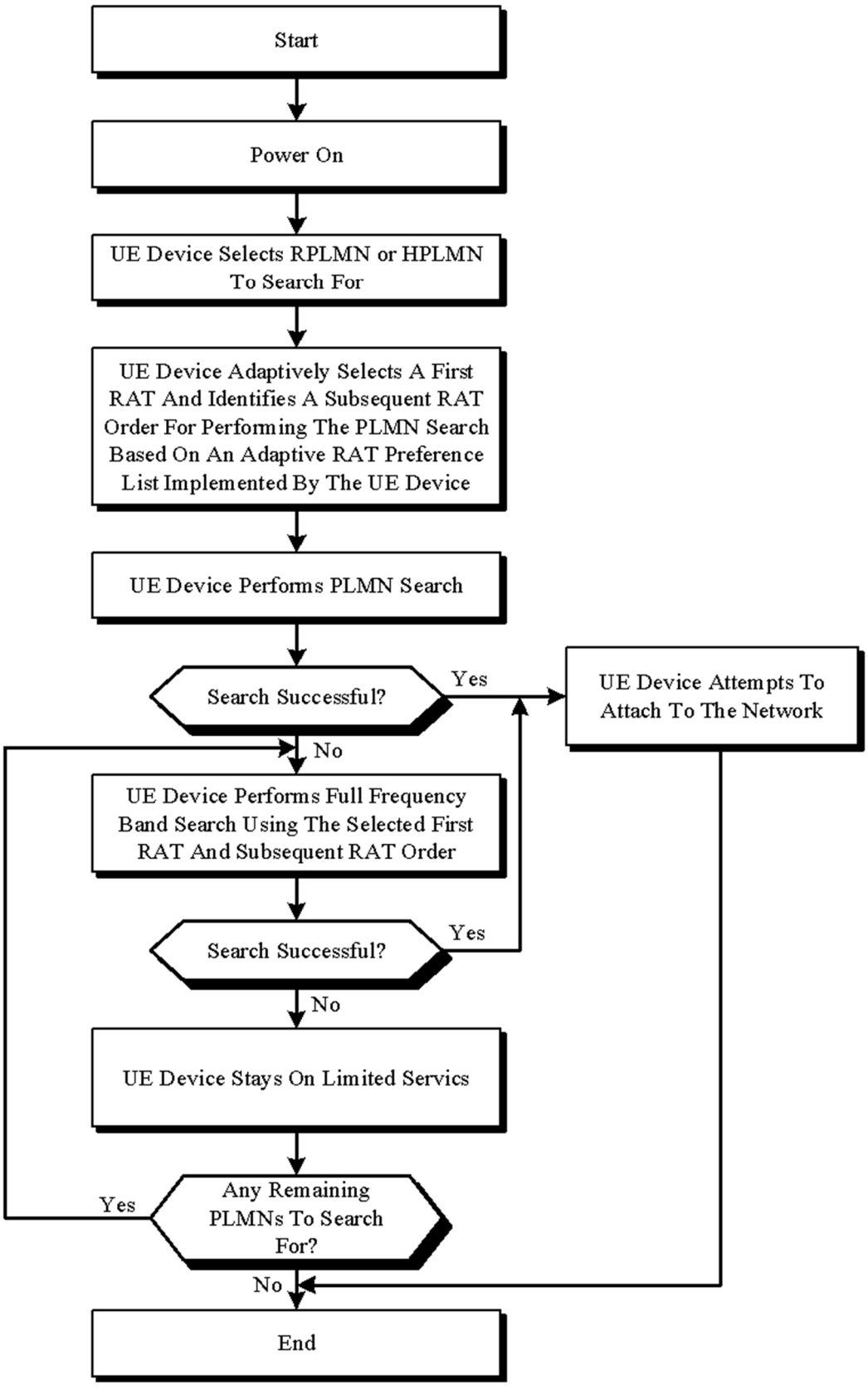
Start
Power On
UE Device Selects RPLMN or HPLMN To Search For
UE Device Adaptively Selects A First RAT And Identifies A Subsequent RAT Order For Performing The PLMN Search Based On An Adaptive RAT Preference List Implemented By The UE Device
UE Device Performs PLMN Search
Search Successful?
Yes
UE Device Attempts To Attach To The Network
No
UE Device Performs Full Frequency Band Search Using The Selected First RAT And Subsequent RAT Order
Search Successful?
Yes
No
UE Device Stays On Limited Servics
Any Remaining PLMNs To Search For?
Yes
No
End

Figure 1

References

1. US Patent Application Publication No. 2020/0053642, entitled “Flexible Radio Access Technology Selection Policy For 5G Mobile Communications”, and filed on August 8, 2019, the entirety of which is incorporated by reference.

2. European Patent Application Publication No. 1830596, entitled “Method And Wireless User Equipment For Position Assisted Network Scanning”, and filed on March 2, 2006, the entirety of which is incorporated by reference.

3. US Patent Application Publication No. 2013/0217386, entitled “Parallel Multi-RAT PLMN Search”, and filed on February 14, 2013, the entirety of which is incorporated by reference.

4. US Patent Application Publication No. 2020069287, entitled “Radio Access Technology (RAT) Selection For NR V2X”, and filed on September 27, 2019, the entirety of which is incorporated by reference.