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Early Determination of SIM Switching in Mobile Telecommunication System

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EARLY DETERMINATION OF SIM SWITCHING IN MOBILE TELECOMMUNICATION SYSTEM

Abstract

A user equipment (UE) in a wireless communication network performs early determination of SIM switching to mitigate delays in SIM switching typically experienced by the UEs when a no-service event has occurred. During frequency band scanning for a carrier network associated with a primary or current SIM in use by the UE, the modem provides an available network indication(s) to an early SIM switching component of the UE, such as a local profile assistant, indicating that a different carrier network has been detected. Responsive to receiving the available network indication from the modem, the early SIM switching component directly switches to another SIM associated with the detected carrier network without having to wait for the UE to scan each remaining frequency of the original carrier network, scan other frequency bands of the original carrier network, or repeat the scanning process for a different SIM associated with a different carrier network.

Background

Mobile phones, cellular-enabled tablets, and other user equipment (UE) often utilize multiple subscriber identity modules (SIMs), thereby allowing the UE the option to connect to multiple cellular networks as needed. However, this multiple-network capability can trigger extensive delays when no-service situations (e.g., no available cellular service, call rejected, etc.) are encountered by the UE. For example, consider a “no service” situation in which an emergency cellular connection (ECC) call is initiated via an ECC dial request while the UE is in airplane mode. In this situation, the default operation is for the UE to attempt to camp on the carrier network associated with the primary SIM (physical SIM or eSIM) as quickly as possible.

However, assuming that a signal from the carrier network on the default frequency band is not found, then the UE conventionally can take either of two approaches. In one approach, the UE can continue to search other bands of the primary carrier network or do a full band search. However, this often can take two minutes or more and is not guaranteed to find an available carrier network. In the other approach, the UE can switch to another SIM (physical SIM or eSIM) and "redial" or re-attempt the ECC call process again with the other carrier network, which further delays the establishment of the ECC call. In another example, the UE attempts to attach to the carrier network associated with a currently selected SIM but encounters an out-of-service (OOS) event, such as when the UE is indoors or outside of the coverage area of the carrier network. In this situation, the default operation for the UE is to take either of the two approaches described above and can experience long delays as the UE attempts to continue scanning the current frequency band, scan other bands of the carrier network, or switch to another SIM associated with a different carrier network.

Description

As described in detail below, an early SIM switching mechanism is integrated into one or more components of a UE, such as the modem or an application processor (AP), to mitigate SIM switching delays when no-service events are encountered. When the UE is scanning a frequency band for a first carrier network associated with a primary/selected SIM and detects a second carrier network associated with a secondary or unselected SIM, the early SIM switching mechanism is notified that the second carrier network is available. The early SIM switching mechanism can directly switch to the SIM associated with the second carrier network without waiting for scanning of the first carrier network to complete or the UE switching to SIMs and repeating the scanning process for their associated carrier networks. As such, the early SIM

switching techniques described herein mitigate delays experienced by the UE when performing SIM switching in no-service situations.

Figure 1, shown below, is a ladder diagram illustrating an early SIM switching example. In this example, the UE is attempting to establish an ECC call while the UE is in airplane mode, and the UE employs multiple SIMs (e.g., SIM1 to SIM3), each associated with a different carrier/network. Also, in this example, the early SIM switching mechanism of the UE is implemented as part of a local profile assistant (LPA). The LPA can be implemented in the AP, modem, or another component of the UE. An ECC dial request is generated and sent to the AP (or another component) of the UE and, in response, the AP powers on the UE's modem. A first protocol stack (e.g., Stack1) of the modem is employed to use the SIM (e.g., SIM1) of the primary carrier (e.g., NW1) and initiates a network scan by scanning an associated frequency band (e.g., frequency1, frequency2, and frequency3) to detect NW1. However, after scanning frequency1, the L1/radio-frequency (RF) module of the UE reports back that NW1 was not detected. Stack1 then initiates a scan of frequency2, and the L1/RF module reports back that a network of a secondary carrier (e.g., NW3) has been detected (e.g., a system information block (SIB) was decoded for NW3). Responsive to receiving the indication that the NW3 has been detected, the modem sends a network availability indication to the LPA indicating that NW3 has been detected on frequency2. The LPA determines that NW 3 is associated with SIM3 of the UE and instructs (or sends a request to) the modem to initialize a second protocol stack (e.g., Stack2) associated with SIM3 and to enable the NW3 carrier profile. Alternatively, the LPA sends a request to the modem for Stack1 to use SIM3 and enable the NW3 profile. The AP then redials the ECC call using SIM3 directly since the availability of NW3 has been previously confirmed during the frequency band scan for NW1. The LPA can perform similar operations in other no-

service situations, such as when the UE employs a physical SIM (PSIM) and multiple eSIMs (eSIM1 to eSIM3) and encounters an OOS event associated with the currently selected SIM.

FIG. 2 illustrates an example method of a UE determining when to perform early SIM switching. In this example, the UE is configured to enable multiple eSIM profiles in one eSIM at the same time, e.g., a multiple enabled profiles (MEP) configuration, or is configured to support only one eSIM profile at a time, e.g., a single enabled profile (SEP) configuration. Also, before a network scan is initiated, the LPA instructs the modem to send available network indications (expected cellular carrier/network) during network scanning. For example, if the modem stack is currently using eSIM1 for carrier/network NW1 and detects the availability of carrier/network NW2 while scanning the frequency band for NW1, the modem is configured to send an available network indication to the LPA indicating that NW2 has been detected. This differs from conventional mechanisms, which do not send an available network indication to the LPA when a carrier network not associated with the current SIM is detected.

The available network indication includes information, such as identifying information of the available/detected network(s), receive (Rx) signal quality, profile state, barred cell information, Internet protocol (IP) core network subsystem (IMS) emergency setting, and so on. The available network identifying information can include information such as the mobile country code (MCC), mobile network code (MNC), or the evolved universal mobile telecommunications system terrestrial radio access network (E-UTRAN) absolute radio frequency channel number (EARFCN) associated with the available network. The profile status information can include the current profile status, eSIM identity (optional for one eSIM), or the logical software exchange interface (LSI) associated with the profile. The barred cell information includes information indicating, for example, that the LPA is not to use the cell.

The LPA can send the available network indication request to the modem before or after network scanning has been initiated at the modem.

The modem protocol stack associated with the currently selected (or primary) SIM initiates network scanning for the associated carrier/network. The modem determines if a network has been detected for each scanned frequency. If a network was not detected for the current frequency, the modem protocol stack scans the next frequency in the band. However, if a network was detected, the L1/RF module of the UE attempts to decode the associated SIB. If decoding fails, the modem protocol stack initiates scanning of the next frequency in the frequency band. If the modem successfully decodes the associated SIB, the modem retrieves carrier information associated with the SIMs being employed by the UE. In one example, the LPA provides the carrier list and information to the modem. If the carrier detected by the modem is not listed in the carrier information provided by the LPA, the modem protocol stack initiates scanning of the next frequency in the band for the current SIM. If the UE supports the detected carrier, the modem sends an available network indication(s) to the LPA to identify the detected network(s). The LPA then updates its carrier list. If additional network scanning is to be performed, the modem protocol stack initiates scanning of the next frequency or frequency band. If additional scanning is not to be performed, the process ends.

Based on the available network indication(s) received from the modem, the LPA directly switches to the SIM associated with the detected network without waiting for this SIM to be selected and the network scan being performed. In some instances, the modem may provide available network indications associated with multiple detected networks to the LPA. Stated differently, the modem may detect multiple different networks associated with multiple different SIMs employed at the UE when scanning for the network associated with the currently selected

SIM. As such, the LPA can determine which of the multiple SIMS to select based on the network carrier profile status provided by the modem in the available network indications. For example, in one configuration, if the UE supports MEP, the LPA selects an enabled carrier profile in the same LSI or different LSI as the current carrier profile. If the LPA selects an enabled profile in another LSI, the LPA can use a manage channel to switch the LSI. In another configuration, the LPA selects a disabled but activated/downloaded carrier profile. In this configuration, the LPA can select another carrier profile in the eSIM if the UE supports SEP, select another carrier profile in the same LSI as the current carrier profile if the UE supports MEP, or select a carrier profile in another LSI as the current carrier profile if the UE supports MEP. The AP issues an enable profile command for the selected carrier profile in each of these options. Also, the AP uses a manage channel to switch LSIs if a profile in a different LSI is selected. In yet another configuration, the LPA can select an inactive carrier profile that is downloaded and enabled in response to receiving a download command and enable profile command from the AP.

In addition to selecting a carrier profile based on network carrier profile status, the LPA can also select a carrier profile based on network quality, switching speed, or global positioning system (GPS) reporting. Consider a first example where the UE supports SEP and the modem sends the LPA an available network indication(s) indicating that carrier networks NW1, NW2, and NW3 are available. The available network indication(s) further includes the Rx power (radio signal received power (RSRP) and signal-to-interference-plus-noise-ratio (SINR)) of the detected carrier network signals and the profile states of the associated carrier profiles. In this example, the NW1 profile (profile1) is inactive, the NW2 profile (profile2) is disabled, and the NW3 profile (profile3) is inactive. If configured to select a carrier profile for SIM switching based on

network quality, the LPA selects the carrier network having the strongest Rx power, which is NW1 in this example. If configured to select a carrier profile for SIM switching based on switching speed, the LPA selects NW2 since the AP only needs to issue an enable command and disable command for profile2. In contrast, the other profiles require an enable command and a download command, which takes more time than the disable command.

Consider a second example where the UE supports MEP and the modem sends the LPA a similar available network indication(s) indicating that carrier networks NW1, NW2, and NW3 are available. However, in the second example, the NW1 profile (profile1) is associated with LSI0 and is disabled, the NW2 profile (profile2) is associated with LSI1 and is enabled, and the NW3 profile (profile3) is associated with LSI1 and is inactive. If configured to select a carrier profile for SIM switching based on network quality, the LPA selects the carrier network having the strongest Rx power, which is NW1 in this example. If configured to select a carrier profile for SIM switching based on switching speed and the current LSI is LSI0, the LPA selects NW2 (LSI0) since the modem only needs to issue a select command for the carrier profile of NW2 and needs to issue a disable and enable command for NW1 (LSI1). The UE is able to present network scanning results to the user based on the available network indications generated by the modem and can also provide a suggested selection order based on the aforementioned operations. The user is then able to select a carrier profile for switching the SIM to attach to a carrier network.

The early SIM switching techniques described above with respect to Figure 1 and Figure 2 differ from conventional mechanisms in that the early SIM switching techniques enable the UE to directly switch to an appropriate SIM after detection of the carrier network associated with that SIM instead of having to complete the current frequency band scan and then switching to a

different SIM or starting a new frequency band scan for the primary/selected carrier. Conventional mechanisms typically do not report the availability of a different carrier network when scanning for the carrier network of the primary or currently active SIM. For example, if the carrier network associated with the primary/selected SIM was not detected during the scanning process, the modem usually reports no service is available even though a different MNO may have been detected. The UE selects another SIM associated with a different carrier and repeats the scanning process for the associated carrier network. This process is repeated for each remaining SIM employed at the UE until the carrier network associated with the currently selected SIM is detected regardless of if another carrier network has been detected during the scanning process. Each full frequency band scan can take up to 45 seconds resulting in conventional mechanisms taking up to 67.5 seconds (45 seconds + (45 seconds / 2)) for the UE to switch to a different SIM and then an additional 45 seconds for each additional SIM switch. However, because the early switching techniques described herein enable the UE to directly switch to a SIM associated with a detected network, these techniques reduce the SIM switching delay by a significant amount (e.g., 45 seconds / 2 = 22.5 seconds).

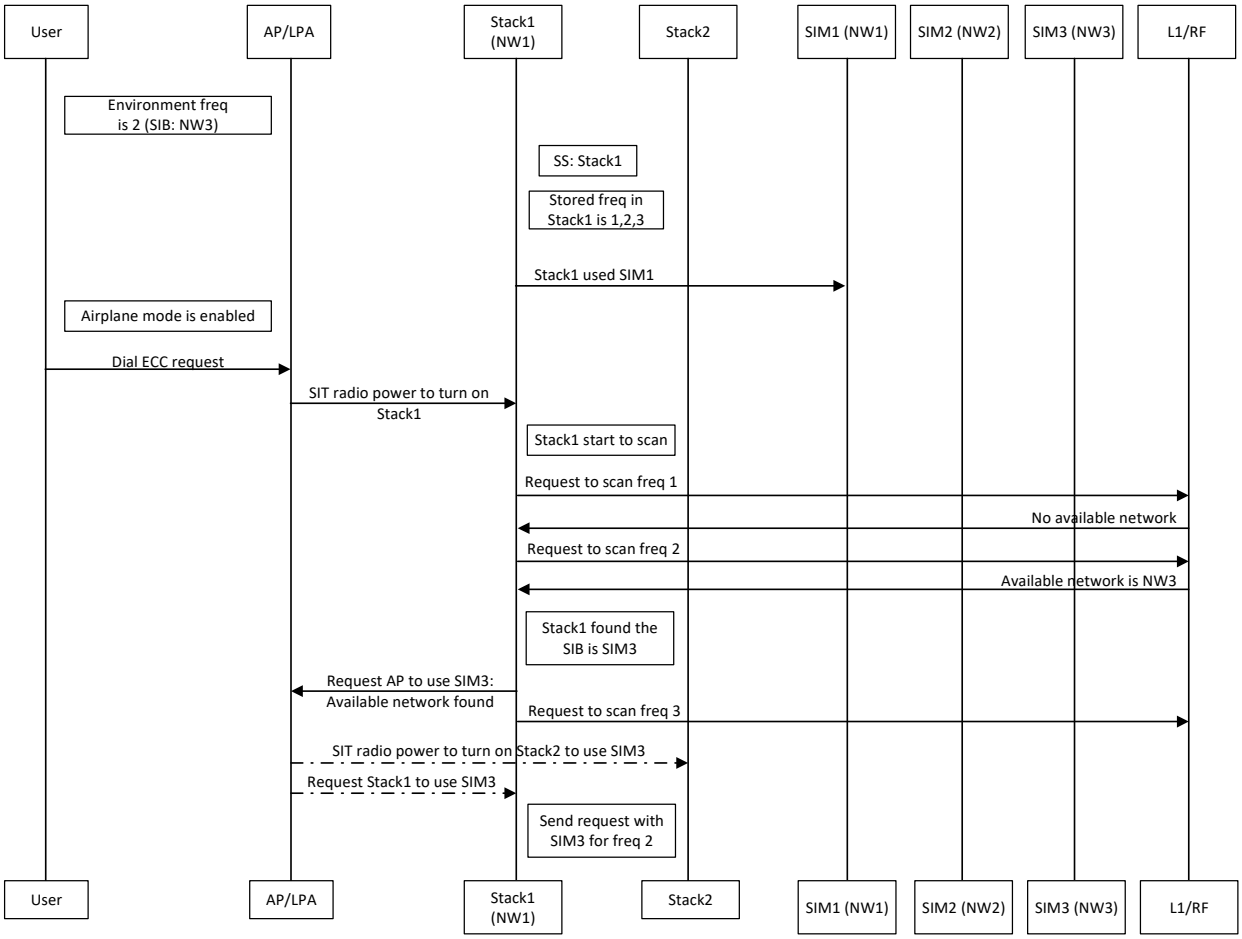
User
AP/LPA
Stack1 (NW1)
Stack2
SIM1 (NW1)
SIM2 (NW2)
SIM3 (NW3)
L1/RF
Environment freq is 2 (SIB: NW3)
SS: Stack1
Stored freq in Stack1 is 1,2,3
Stack1 used SIM1
Airplane mode is enabled
Dial ECC request
SIT radio power to turn on Stack1
Stack1 start to scan
Request to scan freq 1
No available network
Request to scan freq 2
Available network is NW3
Stack1 found the SIB is SIM3
Request AP to use SIM3: Available network found
Request to scan freq 3
SIT radio power to turn on Stack2 to use SIM3
Request Stack1 to use SIM3
Send request with SIM3 for freq 2
User
AP/LPA
Stack1 (NW1)
Stack2
SIM1 (NW1)
SIM2 (NW2)
SIM3 (NW3)
L1/RF

Figure 1

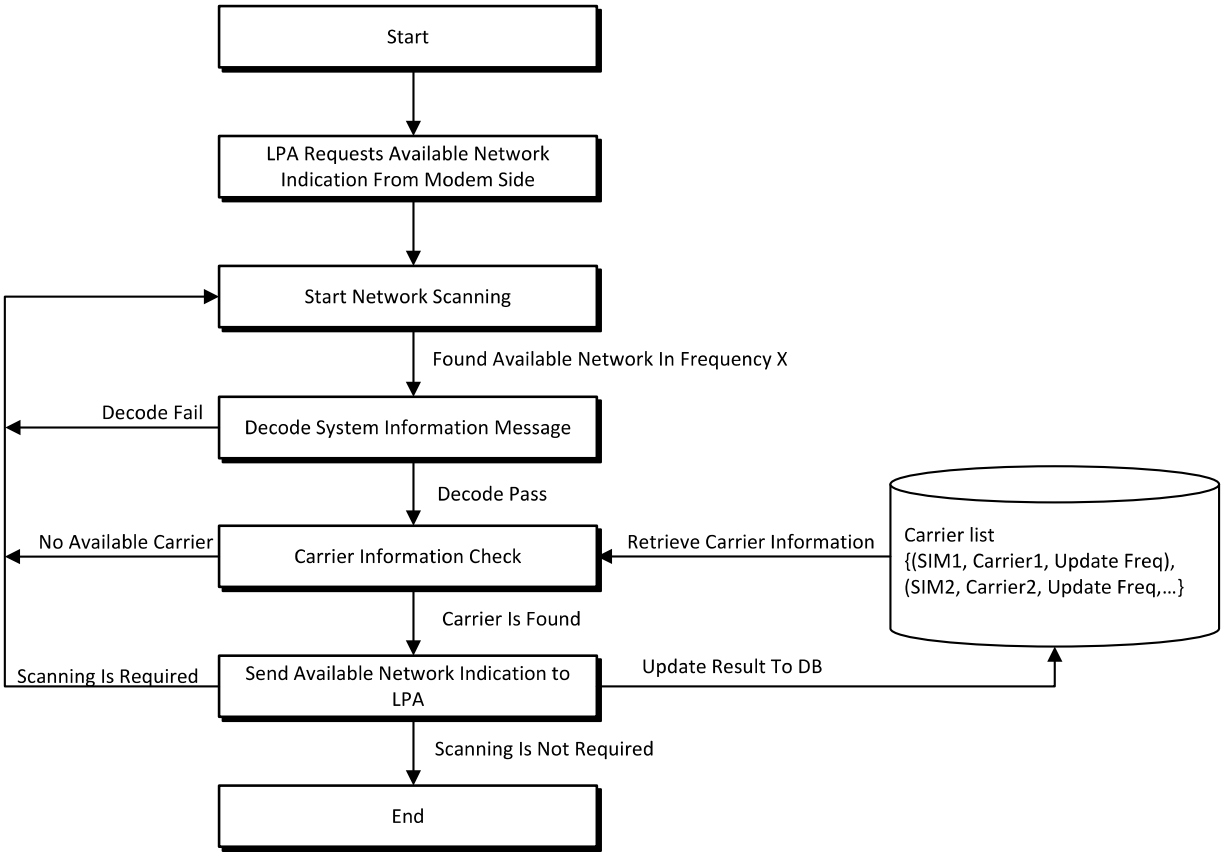

Figure 2

References

1. PCT Patent Application Publication No. 2021/018273, entitled “Method For Switching Operator Networks, And Electronic Device”, and filed on July 31, 2020, the entirety of which is incorporated by reference.

2. Japanese Patent Application Publication No. 2021/118397, entitled “Switching Control Program, Switching Control Method, And Electronic Information Storage Medium”, and filed on January 23, 2020, the entirety of which is incorporated by reference.