A Simultaneous Network Search Scheme for Fast Roaming and Handover of the Simultaneous Voice and LTE Mobile Devices

Minsuk Ko, Myungchul Kim and Sungwon Kang
Korea Advanced Institute of Science and Technology (KAIST), Daejeon, South Korea

Keywords: Fast Roaming and Handover, Simultaneous Voice, LTE.

Abstract: Most of the countries in the world are currently providing 2G or 3G mobile communication services with limited coverage of LTE services. Therefore when an LTE service user moves into or around such countries, the LTE terminal needs to roam or handover to 2G or 3G network for service quality. For LTE terminals that can be connected to 3GPP Legacy (such as GSM, UMTS, and HSPA) and CDMA networks, it normally takes more than 2 minutes to select one of several candidate networks for roaming and 20 seconds to 2 minutes to handover to other networks before getting out of the LTE service area, which is considered very long by many LTE users. This paper proposes a scheme for fast roaming and handover that simultaneously searches for multiple networks with a Dual RF LTE terminal for both voice and data communication. In our experiment with the simultaneous network search implemented in a commercial LTE terminal with dual RF, the network selection time for roaming was reduced by 15% to 40% and the delay time for handover in LTE network was reduced by 90%.

1 INTRODUCTION

Generations of mobile communication technology include the 1st Generation (1G) to the 4th Generation (4G) in accordance with data transmission speeds which have been classified by International Telecommunication Union (ITU).

Only voice communication was available in analog 1G. Data transmission became possible in the 2nd Generation (2G), which was the first digital mobile communication technology. 2G includes Global System for Mobile communications (GSM) in Europe and Code Division Multiple Access (CDMA) in the U.S.A. region. However, their data transmission speed was 14.4 to 64 Kbps so that only SMS and email could be possible.

3G has opened the real mobile communication era. The 3rd Generation Partnership Project (3GPP) in the European region commercialized Wideband Code Division Multiple Access (WCDMA), which includes Universal Mobile Telecommunications System (UMTS) and High Speed Packet Access (HSPA). On the other hand, the 3rd Generation Partnership Project2 (3GPP2) in the U.S.A. region commercialized the Code Division Multiple Access (CDMA2000), which includes 1xRTT and Evolution-Data Only (EV-DO).

While 3GPP was commercialized as the 4G technology with the Long Term Evolution (LTE) in Korea, U.S.A., etc., 3GPP2 gave up developing a 4G technology. Although another 4G technology, Mobile WIMAX, was developed, it is used only in a small number of countries. Therefore, LTE is a predominant 4G technology. However, currently just a few countries including Korea, U.S.A., etc., have started providing LTE and the rest of the countries are still providing 2G or 3G only. Therefore, when the LTE users move into the countries with no LTE networks, voice and data services must be provided through 2G or 3G. Also, even in the countries with LTE network, its coverage may not be as wide as that of 3G, in which case LTE terminals need to handover to 3G network when LTE network is not available.

Since mobile communications are evolutionary technologies, a mobile device for a new wireless network should support the existing ones. Also, the limited coverage of a new wireless network calls for fast roaming and handover between different wireless networks as they are essential for service quality, which operators and terminal manufacturers all aspire to provide (Tu, 2013).

One approach for fast roaming and handover is to directly exchange necessary information between

Ko M., Kim M. and Kang S..
A Simultaneous Network Search Scheme for Fast Roaming and Handover of the Simultaneous Voice and LTE Mobile Devices.
DOI: 10.5220/0005037600360043
In *Proceedings of the 11th International Conference on Wireless Information Networks and Systems* (WINSYS-2014), pages 36-43
ISBN: 978-989-758-047-5

two networks. Another is to make a mobile device search for available network fast, which can save cost and time compared to the former approach. In particular, since LTE terminals with a Dual RF supporting existing wireless networks can be used for simultaneous network search, the network selection time for roaming and handover can be significantly reduced.

1.1 CS Domain and PS Domain

A network comprises of the access network and the core network. The access network is used for users to access to the core network and the core network provides various services including telephony to the users who are connected through the access network.

The core network in turn consists of the Circuit Switched (CS) domain, which is for communications such as voice and SMS, and the Packet Switched (PS) domain, which is for data communication.

In the CS domain, one exclusive physical route between a caller and a callee is established until a telephone call connection is terminated. The route is maintained during communication so that the service is stable and delay is short. On the other hand, in the PS domain, a physical route is established only when data is transmitted in the form of packets and then the route is disconnected until next packets are created to send. Network resources are used only when data are transmitted so that the resources are managed efficiently but delay may be longer than in the CS domain.

1.2 Simultaneous Voice and LTE

Since the LTE technology supports only the PS domain, various technologies were proposed for voice communication, for example, Voice over LTE (VoLTE), Circuit Switched Fallback (CSFB), and Simultaneous Voice and LTE (SVLTE).

For VoLTE, IP packet is used for voice communication in LTE network. However, the LTE service area is still not sufficiently wide and there are interoperability issues among VoLTE services by different providers.

CSFB is a technology used by the LTE service provider who was a 3GPP 3G service provider. It provides 3G WCDMA or GSM for voice communication by disconnecting LTE if communication is needed during data communication. Since LTE is disconnected during voice communication, both voice and data communications are performed in 3G network (Tanaka, 2009). Paper (Tu, 2013) studies the inter-play of voice and data in operational LTE networks and assesses how the popular CSFB-based voice service affects the IP-based data sessions in 4G LTE networks, and vice versa. Their findings reveal that the interference between them is mutual.

SVLTE is a technology used by the LTE service provider who was a 3GPP2 3G service provider. Unlike CSFB, SVLTE can simultaneously transmit data through LTE when voice communication uses CDMA network (Qunhui, 2011). Terminal for this service uses a dual RF: one RF to acquire and register to the 1xRTT CDMA network for voice and the other to acquire and register to the LTE network for data communication. With a dual RF, data packet can be transmitted in the LTE network while voice communication is using the 1xRTT network and the terminal can separately register to LTE and CDMA networks by using different band classes. LTE terminal using a dual RF has two modems, which are connected to separate RF transceivers and antennas for communication to networks: one modem for data communication using LTE and 3GPP Legacy and the other for voice communication using CDMA. Each modem can communicate with the other using message passing.

1.3 Network Registration Procedure

The general procedure for mobile communication terminal to register to a network has three steps as follows: In Step 1, a mobile terminal acquires time and frequency synchronization of the base station using information such as frequency list, mobile country code, and mobile network code in the SIM card. In Step 2, the mobile terminal receives network information that is periodically broadcasted from network after successfully performing Step 1. The network information, which is broadcasted by the base station, includes network type, mobile country code, and basic information for network connection. In Step 3, the mobile terminal performs a registration procedure to the selected network after successful execution of Step 2. In this procedure, Steps 1 and 2 are performed by the terminal itself without assistance of the base station as the network can recognize the terminal only in Step 3. In general, the most time consuming of these steps is Step 1 as it acquires time and frequency synchronization.

2 CONVENTIONAL NETWORK REGISTRATION

This section introduces the conventional network registration procedure and analyzes the conventional roaming and handover.

2.1 Conventional Network Registration Procedure

In the conventional network registration procedure depicted in Figure 1, the terminal first tries to acquire time and frequency synchronization. If the terminal fails to acquire time and frequency synchronization, the network is considered to be unavailable. If the terminal acquires time and frequency, it tries to obtain network information that is broadcasted by the network periodically. If the terminal fails to obtain network information, the network is considered to be unavailable. If the terminal obtains network information, it tries to register to the relevant network. If the terminal fails, the network is considered to be unavailable. If the terminal registers to the network, the network registration has been successfully completed.

In general, service providers based on LTE and CDMA network select a network registration method for roaming and handover of SVLTE terminal. Therefore, network registration is performed in the order of LTE, HSPA, 1xRTT, UMTS, and GSM. A mobile terminal searches for an available network in this order so it searches for LTE, HSPA, and 1xRTT networks sequentially prior to searching for UMTS and GSM networks.

Figure 2 shows the conventional network selection procedure. The terminal sets network priority for search. The priority depends on the policies of service providers. Network search for registration is performed according to the priority order. The conventional network registration procedure is shown in Figure 1. If network registration fails, it tries again for a next network according to the priority order. If the terminal registers to a network, the network selection has been successfully completed.

When the priority is in the order of LTE, EVDO, and UMTS and only UMTS network is available, the terminal tries search in that order and then finally registers to UMTS network.

Handover from LTE network to CDMA network is important when the LTE coverage is not wider than the CDMA coverage. Since the terminal performs the procedure for handover to another network before getting out of the LTE service area, seamless data service can be provided to users even though the data transfer rate becomes somewhat lower.

LTE network may inform available CDMA network information to a terminal for efficient handover. CDMA network information, which LTE network provides, includes frequency information

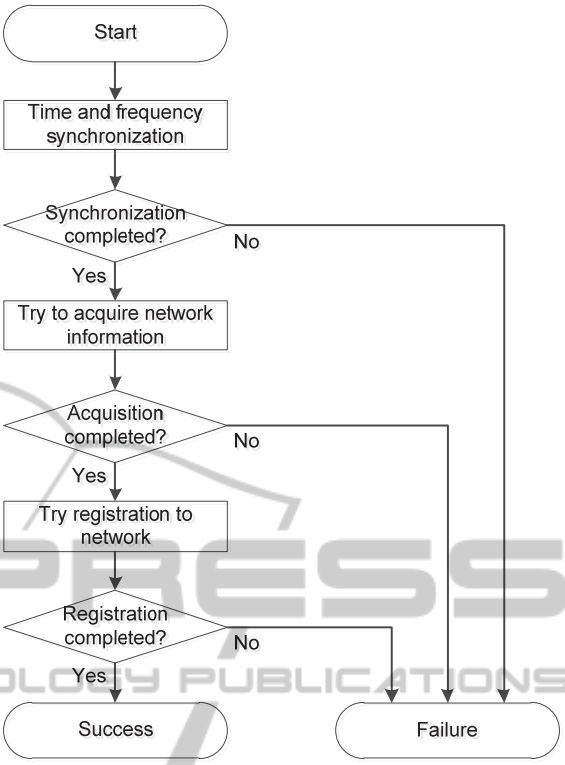

Figure 1: Conventional network registration procedure.

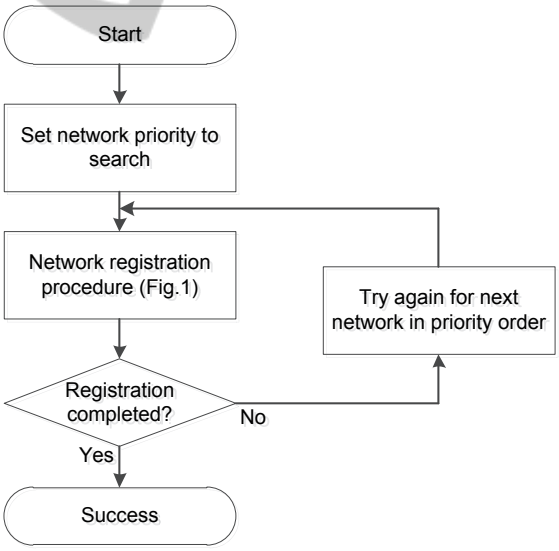

Figure 2: Conventional network selection procedure.

and pseudo noise code (PN Code) of its neighboring base stations. A terminal measures the signal strengths of the neighboring CDMA base stations periodically even though it is registered to LTE network. Therefore, a terminal performs handover from LTE to CDMA network based on the measured

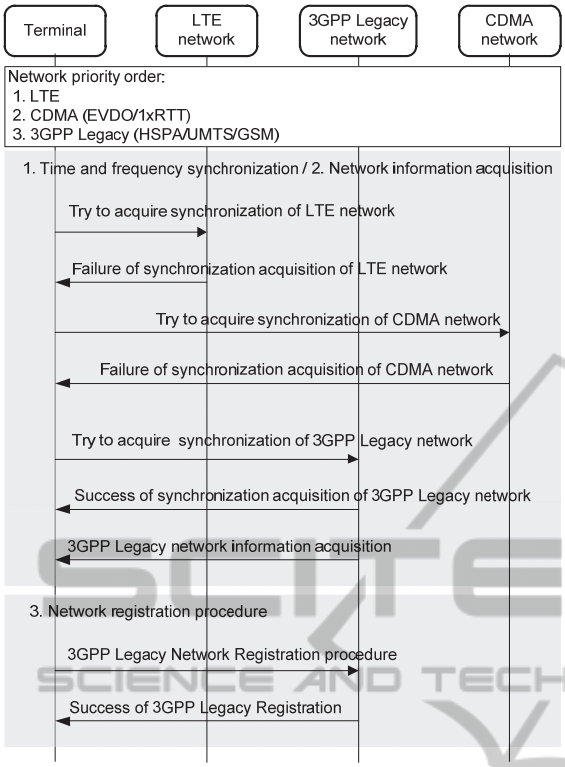

Figure 3: Conventional network registration procedure.

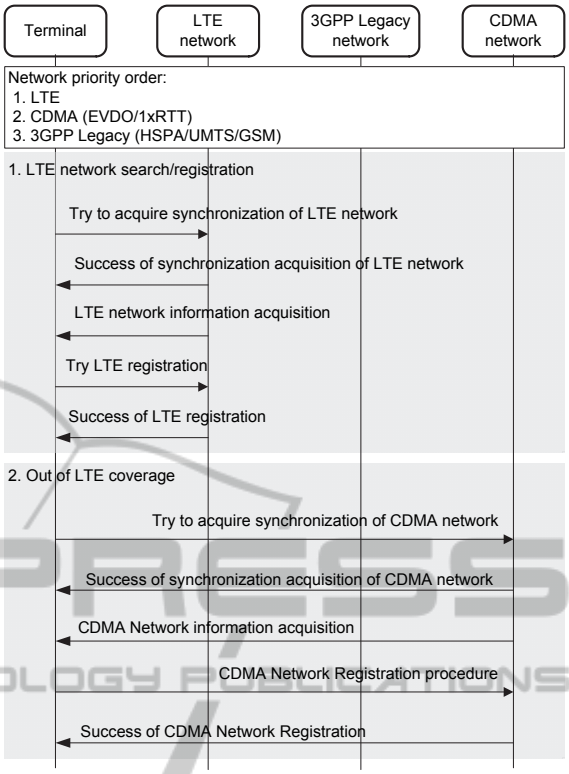

Figure 4: Conventional procedure for handover from LTE to a CDMA network.

signal strength before getting out of the LTE service area.

However, LTE network may not inform available CDMA network information to a terminal. In this case, the terminal selects CDMA network after getting out of the LTE service area.

Because the service area of CDMA network is wider than that of an LTE network, the terminal does not perform handover from CDMA to LTE network. However, since LTE has a higher priority than CDMA, handover occurs when the terminal searches for an LTE network periodically while it is registered to CDMA network.

2.2 Time Analysis of the Conventional Roaming and Handover

In this analysis, the time taken for network registration for roaming was measured using an LTE terminal with Exynos application chipset (Tanaka, 2009) operating in LTE, CDMA (EVDO, 1xRTT), and 3GPP Legacy while signals of LTE and CDMA networks are not available and only HSPA network is available.

Figure 3 shows experimental results of network registration for conventional roaming. Network priority for search is in the order of LTE, CDMA (EVDO/1xRTT), and 3GPP Legacy. The terminal tries to acquire time and frequency synchronization from the LTE network with the highest priority first. Also it is confirmed that there is no available LTE network by failure of its acquisition, which took 1 to 2 seconds. The terminal tries to acquire time and frequency synchronization from CDMA network based on the network priority order. However, it is confirmed that there is no available CDMA network by failure of acquisition of time and frequency of CDMA network which took 140 seconds. Finally, the terminal acquires time and frequency synchronization of UMTS network with the lowest priority. Then it receives network information which UMTS network broadcasts periodically and then completed registration which took 25 seconds.

Handover time from LTE to CDMA was measured in the area that both LTE and CDMA networks are available. LTE network doesn't provide information of CDMA network to a terminal. The signal strength of LTE was gradually reduced while it is registered to LTE network with a higher priority. We measured the time from when LTE signal was reduced to the extent that normal service

is not possible to when LTE terminal with Exynos application chipset completes handover to CDMA network.

Figure 4 shows the conventional procedure for handover from LTE to CDMA network. The terminal completes registration to the LTE network with the highest priority. The strength of LTE signal was gradually reduced for the experiment. Since the terminal doesn't receive CDMA network information from LTE network, it doesn't search for a CDMA network while it is registered to LTE network. When the strength of LTE signal is reduced to the extent that normal service is impossible, the terminal begins to search for a CDMA network. It took 30 seconds to 2 minutes to acquire time and frequency synchronization of CDMA network, receive network information, and complete registration.

The terminal performs search based on the frequency list stored in the SIM card. The search time varies according to the location in the frequency list. That is, if the frequency, which is the same as network frequency, is ahead in the frequency list, it takes approximately 30 seconds and, if it is behind, it takes up to 2 minutes.

The terminal searches for networks in the order of LTE, EVDO, 1xRTT, UMTS, and GSM as described in Section 2. In the roaming area where neither LTE nor CDMA network is available, the terminal can acquire UMTS or GSM network, in which roaming is possible only after completion of search for LTE, EVDO, and 1xRTT network. The search time depends on the frequency of search and, in general, several minutes are required.

Usually the terminal performs handover to another network before getting out of the LTE service area. However, if the signal strength from the LTE network is reduced abruptly or LTE network doesn't inform available neighboring network information, the terminal is disconnected from the LTE network, in which case it should perform an initial network selection to acquire CDMA.

3 SIMULTANEOUS NETWORK SEARCH SCHEME

We propose a simultaneous network search that can replace the conventional sequential one. The proposed search scheme reduces network search time for roaming and handover by a simultaneous search for multiple networks.

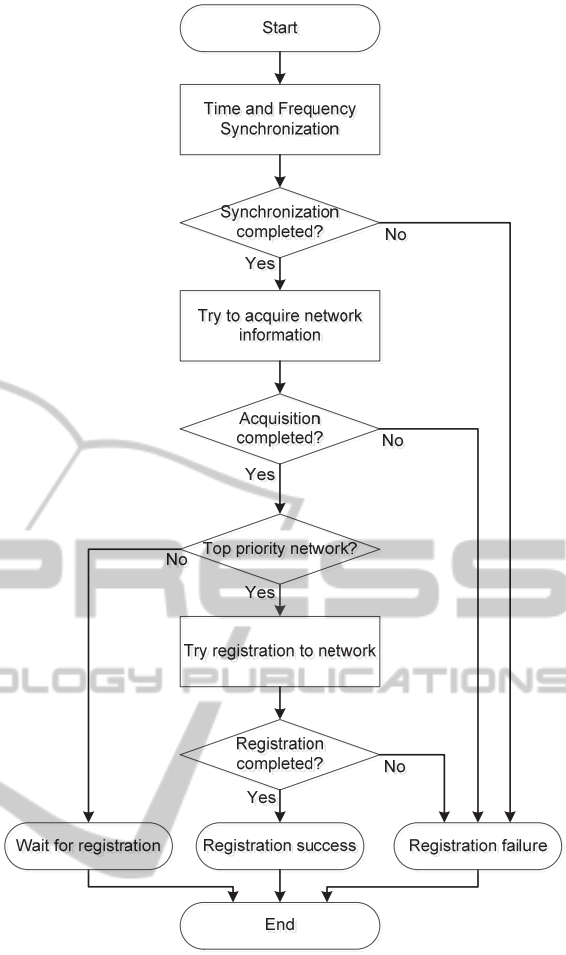

Figure 5: Proposed network registration procedure.

3.1 Scheme to Reduce Time for Network Registration in Roaming and Handover

For SVLTE terminal, two RFs are used at the same time for both voice and data. Therefore, if two networks can be searched simultaneously by using both RFs, the search time can be reduced. In particular, since networks with a lower priority for roaming and handover can be searched while high priority networks are searched, the search will be very efficient.

As with the network registration procedure in Section 1.3, Steps 1 and 2 for acquisition of time and frequency synchronization and reception of network information are performed by the terminal itself without assistance of the base station. Therefore, it is possible that LTE terminal performs Steps 1 and 2 to both of LTE and CDMA networks simultaneously.

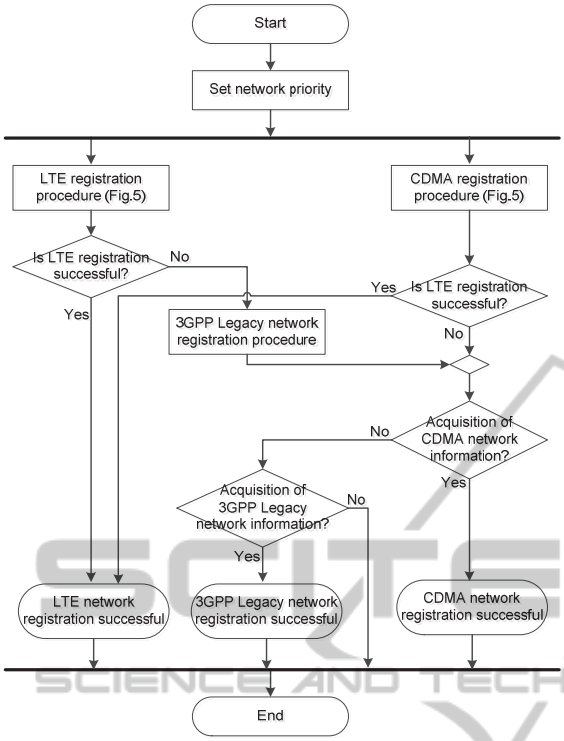

Figure 6: Proposed network selection procedure.

Figure 5 shows the proposed network registration procedure. The terminal tries to acquire time and frequency synchronization of network. If the terminal fails to acquire it, the network is considered to be unavailable. If the terminal succeeds, it tries to receive network information that is periodically broadcasted by the network. If the terminal fails to receive network information, the network is considered to be unavailable. If the terminal receives network information, it checks whether the selected network has the highest priority. If the selected network doesn't have the highest priority, the terminal just waits for network registration. If the selected network has the highest priority, network registration is performed.

Figure 6 describes the proposed network selection procedure using the UML activity diagram (Object Management Group, 2011) to explicitly show parallelism. The terminal first sets network priority for search. The priority depends on the policies of service providers. The order used in this paper is LTE, CDMA, and 3GPP Legacy. The terminal tries to register to LTE network with the highest priority and to CDMA network simultaneously. If the terminal registers to LTE network, the network selection reaches the “LTE network registration successful” state and terminates. If the terminal fails to register to LTE network, it tries to register to 3GPP Legacy network. This procedure is performed while CDMA network registration is performed as in Figure 5. So if the terminal that has currently registered is the highest priority one – LTE network, then it completes the registration process. Otherwise it goes to the "Wait for registration" state. Then if and only if when LTE registration is not successful, it checks whether CDMA network information has been received. If the terminal has received CDMA network information, it registers to CDMA network and network selection terminates.

If the terminal hasn't received CDMA network information, it checks if network information from 3GPP Legacy network has been obtained. If it has, the terminal registers to 3GPP Legacy network and network selection terminates. Otherwise, the initial selection of LTE is resumed.

LTE network may not inform available CDMA network information to a terminal. In this case, the terminal selects a CDMA network after getting out of the LTE service area. In this case, it takes the terminal the same amount of time as the initial network selection to obtain available CDMA network. While a terminal is registered to LTE network, it measures the signal strength of the network periodically in order to reduce the network selection time. If LTE signal is lower than a fixed level, it begins to search for a CDMA network regardless of whether the available network information from the LTE network is received. When a CDMA network is found, time and frequency synchronization and network information acquisition are performed except for its network registration. If the signal strength of LTE network is not high enough for normal service, it begins registration to the CDMA network that it already selected.

3.2 Roaming and Handover Time Analysis for the Proposed Scheme

The time required for roaming was measured using an LTE terminal that uses the Exynos application chipset (Tanaka, 2009) and supports LTE, CDMA (EVDO, 1xRTT), and 3GPP Legacy while signals of LTE and CDMA networks are not available and only HSPA network is available.

Figure 7 shows experimental results with the proposed roaming scheme. Network priority for search is in the order of LTE, CDMA (EVDO/1xRTT), and 3GPP Legacy. The terminal tries to acquire time and frequency synchronization

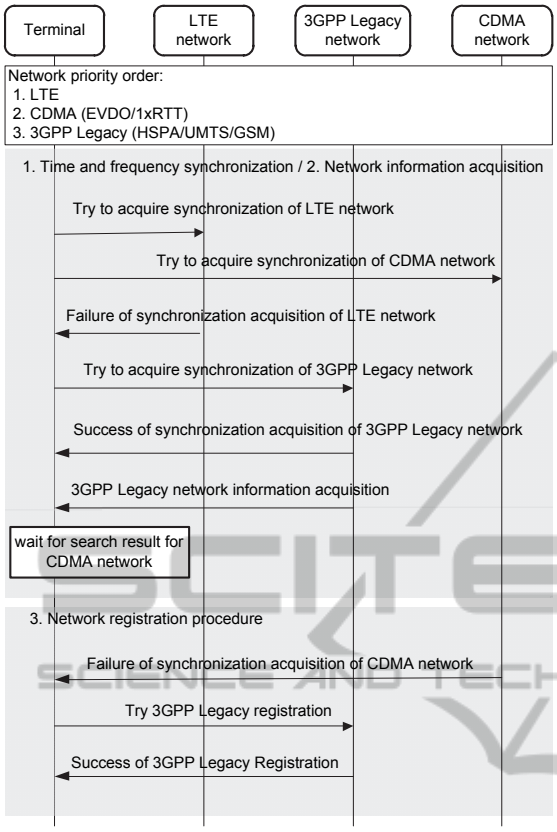

Figure 7: Roaming scenario for experiments with the proposed scheme.

from LTE network with the highest priority first. The terminal tries to acquire time and frequency synchronization from CDMA network with the next priority at the same time because two RF modems for LTE and CDMA can work simultaneously. It is confirmed that there is no available LTE network because it has failed to acquire time and frequency synchronization of LTE while it is acquiring time and frequency synchronization of CDMA. Then the terminal tries to acquire time and frequency synchronization of UMTS. Since signal of a UMTS network is available, the terminal acquires time and frequency synchronization of 3GPP Legacy and then receives 3GPP Legacy network information. Though the terminal acquires time and frequency synchronization of 3GPP Legacy and receives network information, it should wait for search result for CDMA network without registering to 3GPP Legacy network because it is trying to acquire time and frequency synchronization of CDMA. The terminal performs registration to 3GPP Legacy network for roaming after confirming that there is no CDMA network by failure of acquisition of time and frequency synchronization of CDMA.

As described above, the time taken to acquire time and frequency synchronization of CDMA was longer than those of LTE (about 2 seconds) or 3GPP (140 seconds at maximum), which is much shorter than that of CDMA, and the time taken for acquisition of time and frequency synchronization of 3GPP Legacy was 25 seconds, which is longer than that of LTE but shorter than that of CDMA. Compared with the conventional method, which took 167 seconds to select a network for roaming, our proposed method took about 140 seconds to search for LTE, 3GPP Legacy, and CDMA networks simultaneously.

The time for handover to CDMA network for LTE terminal with the Exynos application chipset based on the proposed method was measured in the same experimental environment described in Section 2. Figure 8 shows experimental results using a commercial SVLTE terminal with the proposed handover procedure.

The terminal completes registration to the LTE network with the highest priority. The strength of LTE signal was gradually reduced in the experiment. When the strength of LTE signal is reduced to a fixed level, the terminal begins to search for CDMA networks. In this paper, we set the LTE signal strength level to -100 dBm to begin searching for CDMA network. The terminal confirms availability of CDMA network and receives network information but just maintains time and frequency synchronization without registration. If the terminal considers that signal strength of LTE network is not high enough for normal service, it begins to register to the CDMA network that it already selected. The time for registration to CDMA network is less than 1 second, which is shorter than that for initial registration to CDMA network. Therefore, the terminal can perform fast handover to CDMA network for data communication when it moved out of the LTE service area.

In the conventional method, the same experiment took 20 seconds to 2 minutes. In the proposed scheme, the time was reduced by up to 90% with the exact reduction rate depending on the CDMA frequency. Such a high performance improvement is made possible by using parallelism and also performing Steps 1 and 2 in advance in network registration procedure.

Since two modems search for a network to select, it consumes more battery than a sequential search. But the battery is used just for the initial network selection. So battery consumption is not significant. Also the scheme to reduce the time for handover from LTE to CDMA based on the early

search of CDMA network may consume more battery where LTE signal is weak but service is available. In this paper, the threshold to begin an early search was set to 100dBm. Battery consumption can be reduced by decreasing the number of early searches. More detail experimentation and analysis will be performed further.

4 CONCLUSIONS

The 4G era has begun with the LTE technology. High-speed LTE will provide users with various convenient services such as video conference and streaming.

This paper proposed a scheme for reducing network registration time for roaming and handover time from LTE to CDMA network and demonstrated that network registration time for roaming was reduced by 15% through reduction of time for time and frequency synchronization and network information acquisition of UMTS and GSM. The time depends on the frequency of searching and can be reduced by as much as 45%. Handover time from LTE to CDMA can be reduced by over 90% through reduction of CDMA network search where LTE network doesn't provide CDMA network information.

The proposed scheme makes use of the existing Dual RF in a commercial LTE terminal, and works without change of network configuration and with only change in LTE terminal. As a result, it gives benefits such as fast roaming and handover to users and network operators.

ACKNOWLEDGEMENTS

This work was supported by the National Research Foundation of Korea Grant funded by the Korean Government (NRF-2012R1A2A2A01008244).

REFERENCES

3GPP2 C.S0016-D, 2010. *Over-the-Air Service Provisioning of Mobile Stations in Spread Spectrum Standards Release D*.

3GPP TS 36.304, 2012. *Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) procedures in idle mode*.

3GPP TS 36.331, 2012. *Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC); Protocol specification*.

3GPP TS 24.301, 2012. *Technical Specification Group Core Network and Terminals; Non-Access-Stratum (NAS) protocol for Evolved Packet System (EPS)*.

Samsung Electronics Official website, *http://www.samsung.com/global/business/semiconductor/minisite/Exynos/index.html*.

Tanaka, I., Koshimizu, T. and Nishida, K., 2010. CS fallback function for combined LTE and 3G circuit switched services. In *NTT DOCOMO Technical Journal Vol.11 No.3*.

Qunhui, C., 2011. Evolution and deployment of VoLTE. In *Huawei Communicate*.

Object Management Group, 2011. *OMG Unified Modeling Language (OMG UML). Superstructure, V2.4.1*.

Dahlman, E., Parkvall, S., and Skold, J., 2014. 4G LTE/LTE-Advanced for Mobile Broadband. In *Academic Press*.

Tu G.-H., Peng, C., Wang, H., Li, C.-Y., and Lu S., 2013. How Voice Calls Affect Data in Operational LTE Networks. In *ACM Mobicom*.

Tu, G.-H., Peng, C., Li, C.-Y., Ma, X., Wang, H., Wang, T. and Lu, S., 2013. Accounting for Roaming Users on Mobile Data Access: Issues and Root Causes. In *ACM Mobisys*.