Comparative Analysis of LTE Variants for Suitability in Philippines Setting

Michael Selda

Abstract

Setting up a Long Term Evolution (LTE) Network for research, experimentation, and evaluation using traditional commercially available-off-the-shelve (COTS) hardware comes at a very high price. The three (3) variants of LTE were discussed and thoroughly reviewed for proper assessment in the Philippines setting. Overview of LTE was discussed in this paper. The technical considerations were the network components and software parameters. COTS-based or traditional radio-based system is fixed in design and cannot be modified to adapt to new systems. With SDR, the design is flexible and it can be multiband and multimode. The same SDR can be used whether in 3G, 4G, and even 5G. Only the underlying software has to be modified, reconfigured, or upgraded as necessary without changing the radio front end or the SDR. The review and discussion showed the applicability of SDR based LTE as a viable alternative means to set up an LTE Network without being restricted to traditional COTS hardware-based LTE Network.

Index Terms: **Software Defined Radio, srsLTE, COTS, LTE, 5G Compatibility**

I. Introduction

While the rest of the world is gradually migrating to 5G, the Philippines are yet to fully cover the whole country with 4G LTE signal coverage. The amount of data traffic being that flows within the Mobile Networks today is steadily increasing. This is because smartphones or mobile phones now outnumber their fixed or landline counterpart and is continuously growing in number. Numerous contents such as news, social networking, video, and movies are the most data-consuming applications running over mobile wireless networks. The traffic coverage for the whole Philippines is about 79.8% as of April 2020 [1]. Almost all of this traffic was passing to dedicated hardware with specific functions in an LTE Network or Mobile network in general. To further enhance its performance to an even higher-level, continuous research and development is being done [19]. Experimentation was previously limited to the commercial companies both manufacturing and using this hardware at a prohibitive cost. Commonly, these companies were able to procure commercial-grade mobile communications equipment for experimentations in their laboratories.

Software-Defined Radio (SDR) is becoming popular in the realm of Mobile Communications. The hardware intended to implement both modulation and demodulation is being done in software by a general-purpose computer connected to a radio front end. The programmability and affordability of Software-Defined Radio opened the way in performing experimental research and prototype development. To open up the avenue for research for academics, a few open-source platforms have been created for Mobile Communications. Among these are Open Air Interface (OAI) by Eurocom [2], Open LTE [3] under Affero General Public License, and [4] srsLTE by SRS Group. Software Defined Radio [2] makes it possible to realize different radio communication schemes as well as media access. On these Open Source Systems, some but not all were able to provide a full protocol stack enumerated by 3GPP to build an End-to-End LTE network. srsLTE even extended its functionalities to cover up to 5G compatible.

This paper aims to review the three types of LTE in terms of its applicability in the Philippine setting. The network component and software parameters were thoroughly investigated as the technical requirements in setting up LTE.

Advancement in technology especially in communications is very important for every countries. This study will aid the researchers for future communication setup because even the compatibility issues are tackled in

Communications and Electronics Service
Philippine National Police
Quezon City, Philippines
mvselda@ces.pnp.gov.ph

this papers. Also, the government may use this as reference or guide in setting up more advance technology like 5G.

II. LONG TERM EVOLUTION (LTE)

Since the introduction of 3G in 2001 and the inclusion of packet switching in mobile communications, it offered a significant increase in terms of transmission speeds making it possible for IP-enabled services like video conferencing, Voice Over IP, and web browsing. Many phone manufacturers exploited the business opportunities brought about by this era [15]. After another decade, then came 4G which is now synonymous with Long Term Evolution. The first to deploy LTE was Stockholm, Sweden, and Oslo, Norway in 2009 [5]. Along with it, is a very significant increase in upload and download speed, high-quality video streaming was made possible. It is also possible to connect to the mobile network even while traveling at high speed [20]. The following section is the discussion on the LTE Architecture.

A. LTE Reference Model

The Long-Term Evolution (LTE) Standard is wireless communication, a high-speed data standard for mobile phones and data terminals. It is an upgrade of the 3G system however, it is an all IP network in all its aspect wherein all traffic flows – from a UE to a PDN based on IP protocol within EPS [17].

The basic components of LTE architecture are shown in Figure 1. It consists of the Evolved – UMTS (Universal Mobile Telecommunication Service) Terrestrial Radio Access Network (E-UTRAN) or simply called Radio Access Network (RAN) and the Evolved Packet Core (EPC). E-UTRAN is the one in charge of the radio access network technology while EPC takes care of the core network. The EPC consists of four entities namely: the Serving Gateway, the Packet Data Network Gateway (P-GW), the Mobility Management Entity (MME), and lastly, the Home Subscriber Server (HSS). E-UTRAN consists of the evolved NodeB or ENB and the User Equipment (UE) which is the mobile terminal itself. The UE is composed of the SIM card and the mobile phone, a SIM card, and LTE Dongle, and software implemented LTE Modem with the Software-Defined Radio as the radio front end.

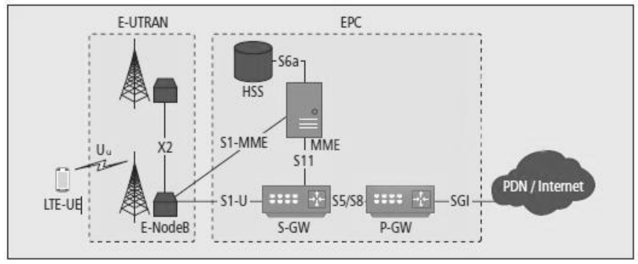

Fig. 1. LTE Network Architecture Reference Model [6]

The functionalities of the LTE includes the following: scheduling and transmission of the broadcast information and paging messages coming from the MM, user plane data routing into the serving gateway, MME entity selection during the procedure for attachment, AS Security, user data stream IP header encryption and compression, reporting configuration for scheduling and mobility as well as measurements. It has also a ,anagement functions for Radio Resource like resources dynamic allocation for UE during uplink and downlink Controls for Radio admission and Radio Bearer [22].

Also, Uu represented by the lightning in color yellow is responsible for assigning radio channels to connect the UE and eNB thereby enabling the transfer of information. eNB is responsible for implementing the different functions and their associated protocols to affect the information transfer through the channels assigned by the Uu.

After a successful connection of the UE to the eNB, S1 composed of S1-U and S1-MME provides a path to connect to the EPC. In this manner, the data plane facilitated by S1-U and the control plane facilitated by S1-MME. eNB connected via S1-MME is in charge of the control plane while eNB connected via S1-U facilitates the flow of data to the S-GW and eventually to the P-GW both of which are responsible for the data plane in the Core Network.

When an eNB needs to connect to another eNB their interface is managed by X2. This usually happens when the UE is in motion between the two eNB requiring handshake or handover or interference is present and the UE needs to connect to a more stable and good quality signal for an uninterrupted connection.

According to [7], an EPC oversees services concerning IP connectivity and this makes an LTE Network and all IP network. The following are the purpose and function of each entity of an EPC. The HSS is a database that includes but is not limited to network performance, user subscription, mobility management, and others. The HSS and MME connect via the S6a interface. The MME is the one in charge of the control plane accessed by the eNB through the S1-MME. It manages the control of the UE. It is responsible for the user authorization and authentication, NAS termination, signaling for control of the mobility of UE. MME is also responsible for S-GW and P-GW selection depending on the type of functionality needed by the UE. S-GW connects to the E-UTRAN via the S1-U interface and oversees data plane communication between the UE through the E-UTRAN. It connects to the MME through S11 and to the P-GW through the S5/S8 interface type. It is responsible for the traffic routing of IP packets to the P-GW and the E-UTRAN. It performs control of accounting and replication of the user traffic when lawful interception is necessary. Lastly, the P-GW is the entity that is facing outward of the LTE Network. It connects to the PDN (Packet Data Network) through the SGi interface. In P-GW is responsible for the assignment of IP addresses to the individual UE. It is tasked to enforce the level of service to a particular UE, such as its uplink and downlink speeds.

III. srsLTE

srsLTE is an SDR-based open source 4G LTE Network created and developed by Software Radio System Company based in Ireland. It is a complete suite open-source LTE platform that includes all the components discussed [8] above namely: LTE eNB, EPC, and UE. According to [9], it is an end-to-end system software suite Linux-based application with all functionalities of an LTE Network compliant to 3GPP Release 15 [10]. Its simplified high-level network architecture diagram is shown in Figure 2 [11].

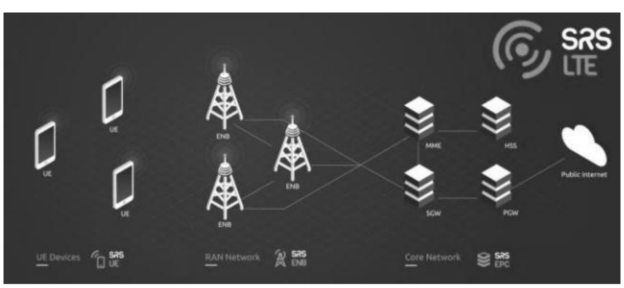

Fig. 2. srsLTE Simplified High-Level Network Diagram.

One novelty of srsLTE Suite is that both srsENB and srsEPC can be housed in the same physical computer further reducing the cost component and complexity of the LTE cell [11] implementation as shown in Fig. 3.

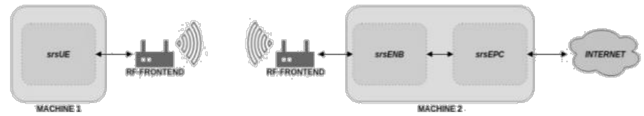

Fig. 3. Basic srsLTE System Architecture.

IV. Methodology

The overview of the LTE was discussed in the previous section of this paper. It is notable that setting up an LTE infrastructure is expensive and needs a lot of consideration [16]. The three (3) types of LTE are compared in terms of their network component and software parameters.

A. Network Component

The network component is composed of user equipment (UE), base station (ENB) and packet core (PC).

1) UE: The srsUE is an LTE User Equipment Modem fully implemented in software. Just like the srsEPC and srsENB, it is a Linux-based application capable of connecting to any LTE Network. Its speed can match other commercially available User Equipment (UE) in the market [9]. Figure 4 shows the xommercially available UE.

Fig. 4. Commercially available Software-Defined Radio.

2) ENB: The srsENB or eNB in its generic term is a base station fully implemented in software and can be installed in a commodity general-purpose computer (x86) or even in a credit card-sized ARM computer such as the Raspberry Pi [12] all running under the Linux Operating System. It forms part of the Radio Access Network (RAN).

3) PC: The srsEPC or Evolved Packet Core is a software implementation of the complete LTE Core Network which can be installed in a commodity general-purpose computer.

B. Software Parameters

The LTE has a strict requirements regarding the code management, 5G Compatibility and status of development. These technical parameters were considered because when the country decided to migrate into more advance communication setup, these will be the requirements.

V. Results and Discussions

In terms of performance, there is no doubt that the COTS-based LTE System outrun SDR Based LTE System. They are designed and optimized using Application-Specific Integrated Circuits which are hardware-based. However, SDR is slowly catching up. In [9]several products are coming out for small cell, macro cell, and LTE access point which are purely SDR Based. This was made possible with the increasing power of computing devices while the price keeps coming down. Recent advances in FPGA SoC and RF programmable transceiver SoC can make SDR catch up fast with COTS-based LTE System [18].

With SDR, the design is flexible: it can be multiband and multimode. The same SDR can be used whether in 3G, 4G, and even 5G. Only the underlying software has to be modified, reconfigured, or upgraded as necessary without changing the radio front end or the SDR. On the other hand, COTS-based or traditional radio-based system is fixed in design and cannot be modified to adapt to new systems. According to [13], showed that it is both a single band and single-mode. They have limited processing capability. However, they have the advantage of lower energy consumption due to optimized design. Traditional radio has complex hardware and contains more analog components. SDR also has its own set of limitations, in [13], it was shown that SDRs-based systems have complex software. In terms of cybersecurity, doing it all in software and cyberspace makes it vulnerable to attacks. As the complexity of computations increase, accordingly so is the capability of its main components such as FPGAs or DSP processors need to be increased accordingly. This then also directly increases the Power consumption of SDR-based systems.

Table 1 shows the summary of network component comparison.

TABLE I.
NETWORK COMPONENT COMPARISON

Types of LTE	UE	ENB	EPC	Operating System
Open Air Interface (OAI)	OAIUE/ COTS	National Instruments/ Ettus USRP and PXIe platforms	Intel x86 PC architectures	Linux
Open LTE	COTS	Ettus Research B2x0 USRP	Intel x86 PC architectures	Linux
srsLTE	srsLTE UE Ettus USRP B2x0/ X3x0 families. BladeRE LimeSDR and COTS	Ettus USRP B2x0/X3x0 families, BladeRE, LimeSDR	Intel x86 PC architectures	Linux

Open Air Interface supports can be installed in a commodity and commercially available Linux-based computing equipment (Intel x86 PC architectures). It can be used with a radio frequency (RF) front end such as National Instruments PXIe and Ettus USRP). The transceiver functionality is realized via a software radio front end connected to a host computer for processing. This is true both for Evolved Packet Core (EPC) and eNB. It supports Commercially Of-The-Shelf (COTS) User Equipment such as Mobile Phones and LTE Dongle.

OpenLTE is also a Linux-based Open Source LTE SDR capable of using commodity Intel x86 PC architectures. It supports software-based eNB implementation of 3GPP LTE however it only includes a simple EPC part [8]. It allows scanning and recording LTE signals and provides DL transmit and receive functionality and UL PRACH transmit and receive functionality. The application provides DL receive and LTE I/Q _le recording can be done using RTL-SDR, HackRF, or USRP B2X0. A simple eNB (LTE-FDD-eNB) can be implemented using USRP B210. It does not support software-based UE and can only be tested using COTS.

Table 2 compares the three Open Source LTE SDR according to Code Management, 5G Readiness, and Status of Development. According to [14] Open Air Interface is complete and provides very good performance. There is complexity in the structure of the code structure. It is 5G ready and is in "Active Development". However [14] did not include OpenLTE in its discussion because due to its limited functionality (e.g., lack of a User Equipment software) and poor robustness, as compared with the other two Open Source Systems considered. It is not yet 5G ready and has seized development as of 2017. srsLTE just like OAI according to [8] is well organized, documented, and easy to customize or modify. It is very complete and provides very good performance. Reference [14] further categorizes srsLTE and OAI, wherein OAI is efficient in terms of computation algorithm employed. srsLTE's codebase is more modular and easier to modify and customize.

Table II.

Software Parameters

Types of LTE	Code Management	5G Compatible	Status of Development
Open Air Interface (OAI)	Very complete and provides very good performance, structure of code is complex	compatible	Active (updated last 2020)
Open LTE	Well organized, documented and easy to customize or modify, incomplete and many features are still unstable or under development	Not compatible	Inactive (updated last 2017)
srsLTE	Well organized, documented and easy to customize or modify, very complete and provides very good performance	compatible	Active (updated last 2020)

VI. Conclusions

Traditional LTE Network can be implemented using a Software Defined Radio based Open-source LTE system. srsLTE performs just like the COTS LTE Network but the main difference is that all network components are implemented in software. User Equipment such as smartphones, tablets with SIM cards, LTE dongles can connect to this network just like in traditional networks. srsLTE can interface with different brands of SDR, only the driver has to be updated accordingly. srsLTE shares the ecosystem with other SDR-based Open-source LTE systems such as OAI and openLTE.

Acknowledgment

The authors would like to thank the Philippine National Police specifically the Communications and Electronics Department for the support of this study. The untiring support of Dr. Ira Valenzuela is greatly appreciated without which this paper will not come into full fruition.

References

1. opensignal. (2020) opensignal. [Online]. https://www.opensignal.com/reports/2020/04/philippines/
2. mobile-network-experience
3. OpenAirInterface. (2020) OpenAirInterface. [Online]. http://www.openairinterface.org/
4. openLTE. (2020) openLTE. [Online]. http://openlte.sourceforge.net/
5. srsLTE. (2020) srsLTE Github. [Online]. https://github.com/srsLTE/
6. Brainbridge. (2019) From 1g To 5g: A Brief History Of The Evolution Of Mobile Standards. [Online]. https://www.brainbridge.be/news/from-1g-to-5g-a-brief-history-of-the-evolution-of-mobile-standards
7. Ali Esmaeily. (2018, June) Study of RAN slicing using SRS LTE in a real SDN-NFV Platform. Internet.
8. Ester Muñoz Sánchez. (2018, February) Study of RAN slicing using SRS LTE in a real SDN-NFV platform. Electronic.
9. Paul Sutton. (2020) srsLTE. [Online]. https://docs.srslte.com/en/latest/general/source/index.html
10. Francesco Gringoli et. al, "Performance Assessment of," IEEE Wireless Communications, vol. 1536-1284, no. 18, pp. 10-15, October 2018. [Online]. https://sci-hub.st/10.1109/mwc.2018.1800049
11. Paul Sutton. (2019) srsLTE. [Online]. https://github.com/srsLTE/srsLTE
12. Paul Sutton. (2020) srsEPC. [Online]. https://docs.srslte.com/en/latest/srsepc/source/1_epc_intro
13. srsLTE. [Online]. https://docs.srslte.com/en/latest/app_notes/source/index.html
14. Mamatha R. Maheshwarappa. (2016, August) [Online].https://core.ac.uk/download/pdf/80845992.pdf
15. Navid Nikaein. (2020, August) OpenAirInterface. [Online]. http://www.eurecom.fr/fr/publication/4371/download/cm-publi-4371.pdf
16. S. Chen, J. Zhao and Y. Peng, "The development of TD-SCDMA 3G to TD-LTE-advanced 4G from 1998 to 2013," in IEEE Wireless Communications, vol. 21, no. 6, pp. 167-176, December 2014, doi: 10.1109/MWC.2014.7000985.
17. T. Anugraha, K. Anwar and S. P. W. Jarot, "Cellular Communications-based Detection to Estimate Location of Victims Post-Disaster," *2019 Symposium on Future Telecommunication Technologies (SOFTT)*, 2019, pp. 1-5, doi: 10.1109/SOFTT48120.2019.9068650.
18. X. Jiao, W. Liu, M. Mehari, M. Aslam and I. Moerman, "openwifi: a free and open-source IEEE802.11 SDR implementation on SoC," *2020 IEEE 91st Vehicular Technology Conference (VTC2020-Spring)*, 2020, pp. 1-2, doi: 10.1109/VTC2020-Spring48590.2020.9128614.

19. P. Gawłowicz and A. Zubow, "Demo abstract: Practical cross-technology radio resource management between LTE-U and WiFi," *IEEE INFOCOM 2018 - IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS)*, 2018, pp. 1-2, doi: 10.1109/INFCOMW.2018.8406905.
20. C. A. G. Hilario *et al*., "LokaLTE: 600 MHz Community LTE Networks for Rural Areas in the Philippines," *2020 IEEE Global Humanitarian Technology Conference (GHTC)*, 2020, pp. 1-8, doi: 10.1109/GHTC46280.2020.9342849.
21. H. M. Hizan *et al*., "Multiservice wireless network testbed design using SDR and RoF platforms," *2016 IEEE Asia-Pacific Conference on Applied Electromagnetics (APACE)*, 2016, pp. 369-372, doi: 10.1109/APACE.2016.7916462.
22. S. Lange *et al*., "Performance benchmarking of a software-based LTE SGW," *2015 11th International Conference on Network and Service Management (CNSM)*, 2015, pp. 378-383, doi: 10.1109/CNSM.2015.7367386.
23. P. Gawlowicz, A. Zubow and A. Wolisz, "Enabling Cross-technology Communication between LTE Unlicensed and WiFi," *IEEE INFOCOM 2018 - IEEE Conference on Computer Communications*, 2018, pp. 144-152, doi: 10.1109/INFOCOM.2018.8485984.