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LTE NETWORK DEPLOYMENT BASED ON OPEN-SOURCE SOLUTIONS

Abstract

In recent years, the landscape of LTE network deployment has experienced a significant shift from reliance on proprietary solutions provided by established vendors to the exploration of open-source alternatives. Open-source solutions have gained traction due to their cost-effectiveness and flexibility, allowing network operators to customize their deployments according to specific requirements and preferences. This article examines the deployment of a 4G LTE network based on open-source solutions. In the context of open-source, the options of using software and hardware for network deployment were discussed. Through meticulous analysis and testing procedures, a viable and robust solution for 4G LTE deployment based on open-source projects is outlined. The aim of this paper is to explore the possibility of 4G deployment based on open-source projects and provide a potential option for deployment. Through this exploration, the article contributes valuable findings to the evolving field of telecommunications, paving the way for future advancements and innovations in open-source LTE network technologies.

Key words: LTE, open-source, private network, deployment.

Introduction

Nowadays, open-source solutions allow for the implementation of a large number of different projects, and every year, the open-source movement is becoming more and more popular in the engineering community. The field of cellular communication networks is no exception.

LTE cellular mobile networks have long been in use around the world, and a large number of commercial solutions have been implemented. They have also become the starting point for further progress beyond the current generation of mobile cellular networks to lead the way to fifth-generation mobile networks. Open-source solutions have emerged as a viable option for LTE network deployment (private networks, testbeds), offering advantages such as cost-effectiveness, flexibility, and customization options. By leveraging open-source software, organizations can reduce dependency on proprietary vendors, lower costs, and have more control over their network infrastructure. However, it's crucial to acknowledge that while open-source LTE solutions provide significant benefits, they may not be universally applicable to all use cases or requirements. A lot of open-source projects were created for testing, experimental purposes, etc. That is, these projects are PoC (proof-of-concept) solutions. But, at the same time, it is a good option for students to studying this network generation.

Literature review

While commercial solutions for LTE network deployment have traditionally dominated the market, there is a growing interest in leveraging open-source solutions to build and optimize LTE networks. This literature overview explores the evolution and significance of LTE network deployment using open-source solutions.

A number of scientific papers have been devoted to 4G test networks deployed on the basis of open source in various aspects of use. In particular, [1] shows how to set up an LTE cellular network for experimental research and measurements, relying on standard equipment and open-source software. Paper [2] describes how to build an enterprise-level private LTE/5G network. There

are recommendations on the use of certain software and hardware. The article also provides a basic deployment scheme.

This article [3] describes a network testbed that allows students to experiment with a fully functional 4G LTE system without a radio. This test system simulates a realistic 4G LTE deployment, helping students gain valuable knowledge of cellular networking.

The next researches works are concerned with the use of OAI (OpenAirInterface) solutions for LTE testbeds deployment. In the first paper [4], the network was deployed using the OAI and OAISIM (OpenAirInterface System Emulation) modules to emulate an LTE network. The second paper [5] shows OAI as a flexible platform for the open LTE ecosystem and playground. It demonstrated a case study of using OAI to deploy a low-cost open LTE network using common hardware with standard LTE-compatible devices. It also shows the possibilities of platform reconfiguration.

The landscape of LTE network deployment is continually evolving, with emerging technologies such as 5G and beyond posing new challenges and opportunities. Researchers are exploring the integration of open-source solutions with these advanced technologies to create synergistic and future-proof telecommunications infrastructures. Exploring novel approaches, such as edge computing and network slicing, is also a focus of ongoing research [6-9].

Thus, the literature reviewed underscores the growing interest in utilizing open-source solutions for LTE network deployment. The studies discussed highlight practical applications, such as LTE testbeds and private networks, emphasizing the flexibility and adaptability of open-source solutions.

Main provisions

The aim of this article is to provide information about the successful deployment and results of testing a 4G LTE network based on open-source solutions. To achieve this goal, the following scientific tasks were solved:

1. To explore existing open-source projects for the implementation of 4G networks and select potential solutions.
2. To develop a network diagram.
3. To deploy and test the LTE network.

An overview of open-source projects for LTE. Generally, open-source LTE solutions provide the necessary components for building and operating an LTE network, including the evolved packet core (EPC), radio access network (RAN), and user equipment (UE).

Software. There are a large number of different open-source projects for EPC deployments. Open-source implementations of the 4G core have become a viable alternative to proprietary solutions, offering greater transparency, flexibility, and cost-effectiveness. Thus, the following popular open-source solutions can be identified for deploying the core of the fourth-generation cellular network:

- srsEPC [10];
- SD-CORE (OMEC) [11];
- Magma [12].

All projects use virtualization of network functions to ensure the operation of basic network functions. It is important to note that there are many homebrew projects with separate network functions implemented in different languages and ways that meet 3GPP requirements.

Both for EPC and RAN deployments, there are a large number of different open-source projects. All of them comply with 3GPP specifications. Therefore, the following projects can be considered for LTE RAN deployment:

- OpenAirInterface eNB [13];
- srsRAN [14].

Hardware. Based on a number of recommendations from various sources, the equipment for deploying private cellular networks should be divided into two components: devices for deploying network core and software part of the BS, and the device for receiving and transmitting signals.

Network Core:

- physical and virtual servers;
- using virtual machines;
- example: a virtual machine on a server or on your PC.
- Radio Access Network:
- for the software solution, similar to the kernel, the use of single-board computers (for example, the Raspberry PI);
- for signal receiving and transmission, use SDR (Software Defined Radio) devices [15].

Recommendations to making choice regarding hardware. It is worth noting that all hardware should be selected in accordance with the requirements of the software that will be used in the deployment process. Thus, we should pay attention to the following technical characteristics of the devices:

- processor manufacturer (most open-source projects work exclusively with Intel Core processors);
- number of processor cores;
- RAM and ROM capacities;
- availability of all necessary physical input and output interfaces;
- SDR manufacturer (some open-source projects for RAN support work with specific SDRs);
- SDR operating frequency and sampling rate (sometimes there may be problems with the configuration of eNodeB files due to non-compliance with the requirements).

LTE network deployment. First of all, the general network scheme was developed. It consists of the following components (Figure 1):

- CORE – network core;
- RAN – base station;
- UE – user equipment.

Figure 1 – The network scheme

To deploy an LTE network based on open solutions, the following software and hardware solutions were selected (all located on the same subnet and connected to the same virtual switch (Figure 2, p. 43), (Table 1). The diagram of the deployed network is shown in Figure 3 (p. 43). It includes the connection between all deployed network components, IP addresses, software and hardware. Additionally, Grafana monitoring systems (Monitoring-4G, RAN Logging and Monitoring) were deployed.

Table 1 – Software and hardware projects for network deployment

#	Component	Software/hardware solution
1.	Network Core	SD-CORE/Virtual machine on the server
2.	RAN (Radio Access Network)	srsENB/Raspberry PI, LimeSDR
3.	RIC (RAN Intelligent Controller)	SD-RAN/ Virtual machine on the server
4.	SMO (Service Management Orchestration)	Aether ROC/Virtual machine on the server
5.	UE (User Equipment)	GRSIMWrite4.2.10/smartphone with LTE support, blank SIM-card

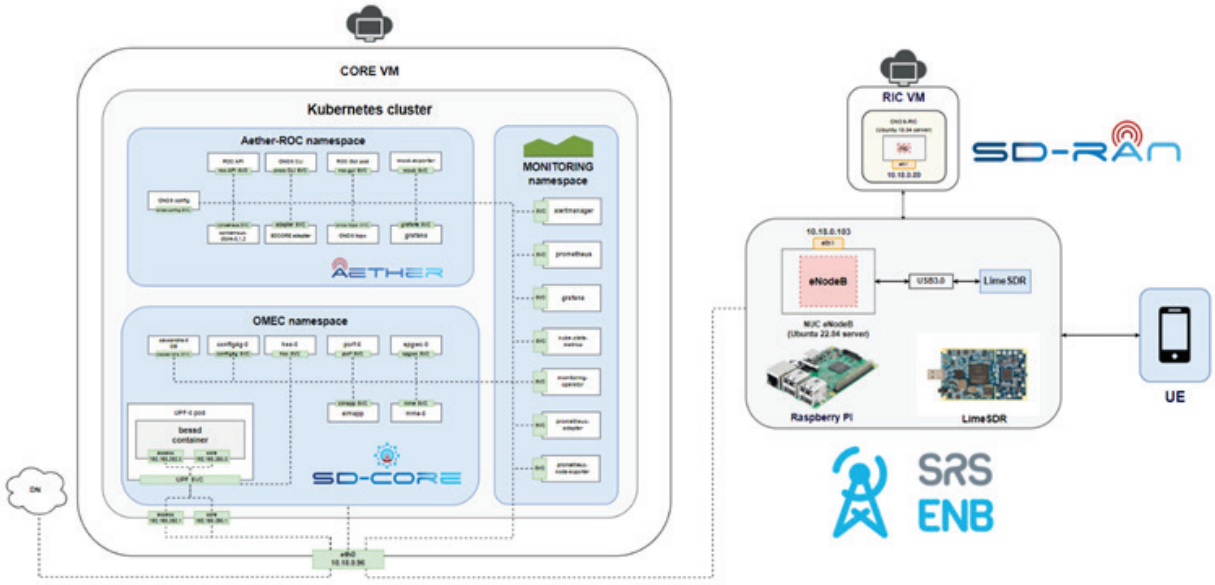

Figure 2 – The full deployment scheme

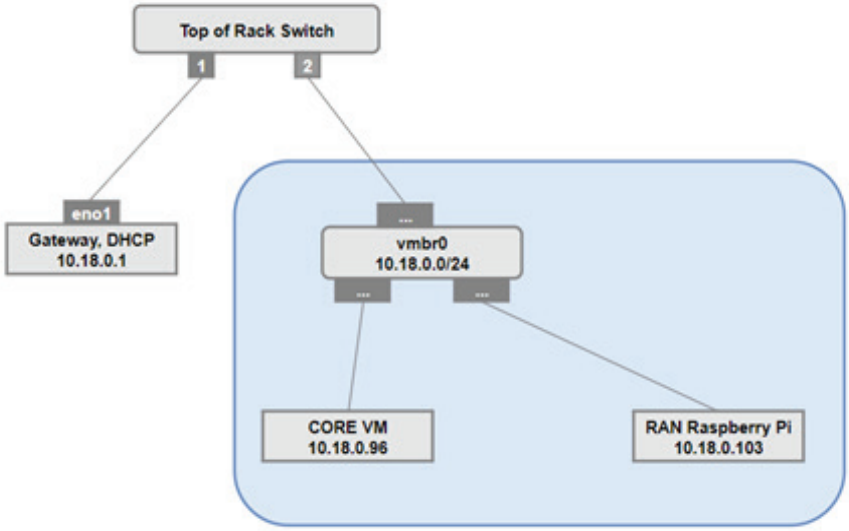

Figure 3 – The network diagram

Network testing. After all the necessary configurations the base station was launched, the network core is in a constantly working state (Figure 4).

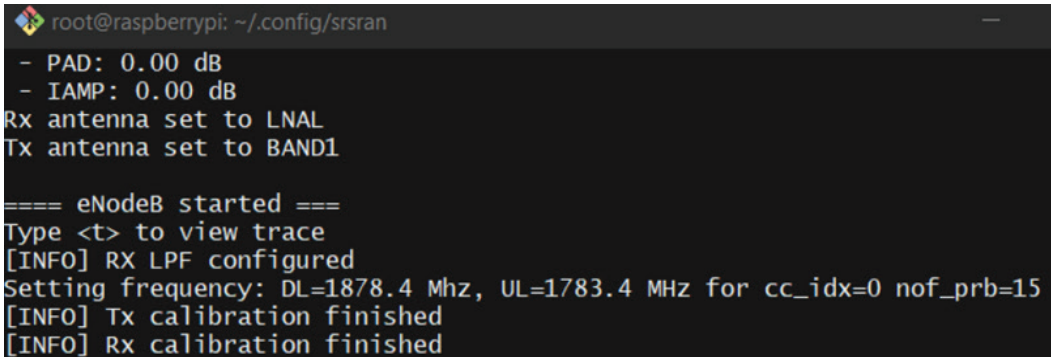

Figure 4 – Base station launching

```
LRACH:  tti=1811, cc=0, pci=1, preamble=50, offset=42, temp_crnti=0x46
User 0x46 connected
```

Figure 5 – UE attachment

The srsENB also is providing function of metrics trace. In our case, we saw the next metrics during testing (Figure 6).

			DL							UL							
rat	pci	rnti	cqi	ri	mcs	brate	ok	nok	(%)	pusch	pucch	phr	mcs	brate	ok	nok	(%)	bsr
lte	1	46	15	0	19	1.1M	121	0	0%	18.5	18.5	40	22	194k	47	0	0%	0.0
lte	1	46	14	0	20	1.1M	118	0	0%	14.0	14.0	40	17	163k	52	6	10%	0.0
lte	1	46	14	0	19	1.1M	119	0	0%	6.5	6.6	40	9	149k	89	5	5%	39.0
lte	1	46	13	0	19	1.1M	131	12	8%	6.4	6.3	40	8	143k	98	3	2%	0.0
lte	1	46	14	0	20	1.1M	119	6	4%	6.6	6.7	40	9	102k	56	3	5%	0.0
lte	1	46	14	0	20	1.1M	125	12	8%	6.9	6.9	40	10	216k	135	17	11%	0.0
lte	1	46	13	0	18	1.1M	135	3	2%	7.2	8.1	40	9	211k	120	2	1%	0.0
lte	1	46	12	0	19	1.1M	128	12	8%	15.7	16.0	40	19	294k	70	7	9%	0.0
lte	1	46	13	0	19	1.1M	128	0	0%	19.5	19.6	40	21	251k	68	0	0%	0.0
lte	1	46	13	0	20	1.1M	143	16	10%	19.4	19.6	40	22	497k	109	4	3%	0.0
lte	1	46	13	0	19	1.1M	128	1	0%	19.8	19.9	40	22	306k	68	0	0%	0.0

Figure 6 – metrics trace

As a result of this variant of deploying an LTE network based on open-source solutions, a user was successfully registered in this network, which can be seen on the monitoring (Figure 7). The following information is available: the status of the base station (eNodeB Status), the number and information (IMSI) about active users (Active subscribers and Subscriber info, respectively), graphically displayed active user time in the network and throughput on two channels Tx Bitrate (Transmitter), Rx Bitrate (Receiver) (current and for the entire time the user is in the network).

Figure 7 – 4G monitoring system

The network performance was tested in various ways, including downloading files to and from the device to the cloud, and video communication using Google Meet. During this, data transfer speeds were measured.

Material and methods

Analyzing existing research in this area, collecting the necessary data, and synthesizing it.

Results and Discussion

With the open-source community, even such complex projects as the deployment of private cellular networks, which require significant practical skills and theoretical knowledge, can be implemented.

Despite a number of difficulties during the project, the network was successfully deployed in the laboratory, which allows for further testing, improvement, and study by students.

Work is currently underway to improve the fourth-generation network by deploying near-RT RIC (near Real Time) and xApps (microservice-based applications to continuously improve the efficiency of RAN spectrum use), which will generally allow controlling and optimizing RAN functions and resources. We are also testing the network with more number of UEs.

Conclusion

Thus, this research contributes valuable insights and practical experiences to the telecommunications industry, affirming that open-source solutions offer a promising avenue for future cellular network deployments, in particular LTE. As open-source projects continue to evolve and expand, they hold the potential to drive further advancements and innovations in the telecommunications field.

Furthermore, the deployed network has successfully passed laboratory tests, paving the way for further improvements and study by students. This demonstrates the prospects for using open solutions for education and research in higher education institutions, helping to improve the quality of education and the training of future specialists in this field.

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АШЫҚ БАСТАПҚЫ КОД НЕГІЗІНДЕ LTE ЖЕЛІСІН ОРНАТУ

Андатпа

Соңғы жылдары LTE желілерін орнату саласында белгілі вендорлар ұсынатын меншікті шешімдерге тәуелділіктен ашық бастапқы кодты баламаларды зерттеуге қарай жылжу өзгерісі байқалады. Ашық кодты шешімдер үнемділігі мен икемділігімен танымал болды, бұл желі операторларына оларды нақты талаптар мен артықшылықтарға сәйкес реттеуге мүмкіндік берді. Мақалада ашық бастапқы кодты шешімдер негізінде 4G LTE желісін орнату қарастырылады. Open-source контекстінде желіні орнату үшін бағдарламалық жасақтама мен аппараттық құралдарды пайдалану жағдайлары айқындалды. Мұқият талдау мен тестілеу нәтижесінде ашық бастапқы кодты жобаларға негізделген 4G LTE желісін орнату үшін өміршең әрі сенімді шешім ұсынылды. Мақаланың мақсаты ашық бастапқы кодты жобалар негізінде 4G желісін орнату мүмкіндігін зерттеу және орнату нұсқаларын ұсыну. Осы зерттеудің арқасында мақала болашақ ашық бастапқы кодты LTE желілік технологиясының жетістіктері мен инновацияларына жол аша отырып, телекоммуникацияның дамып келе жатқан саласына құнды үлес қосады.

Тірек сөздер: LTE, open-source, жеке желі, орналастыру.

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РАЗВЕРТЫВАНИЕ СЕТИ LTE НА ОСНОВЕ РЕШЕНИЙ С ОТКРЫТЫМ ИСХОДНЫМ КОДОМ

Аннотация

В последние годы в сфере развертывания сетей LTE наблюдается значительный сдвиг от зависимости от проприетарных решений, предлагаемых известными вендорами, к изучению альтернатив с открытым исходным кодом. Решения с открытым кодом завоевали популярность благодаря своей экономичности и гибкости, позволяющей операторам сетей настраивать их в соответствии с конкретными требованиями и предпочтениями. В данной статье рассматривается развертывание сети 4G LTE на базе решений с открытым исходным кодом. В контексте open-source рассмотрены варианты использования программного и аппаратного обеспечения для развертывания сети. В результате тщательного анализа и тестирования было предложено жизнеспособное и надежное решение для развертывания сети 4G LTE на основе проектов с открытым исходным кодом. Цель данной статьи – изучить возможность развертывания сети 4G на базе проектов с открытым исходным кодом и предложить потенциальный вариант развертывания. Благодаря этому исследованию статья вносит ценный вклад в развивающуюся область телекоммуникаций, прокладывая путь для будущих достижений и инноваций в области технологий сетей LTE с открытым исходным кодом.

Ключевые слова: LTE, open-source, частная сеть, развертывание.

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