Enhanced Spectrum Sensing Techniques for 5G New Radio (NR) and Long-Term Evolution (LTE) Utilizing Unet++ Deep Learning Network

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***Abstract*—The 5G New Radio (NR) technology emerged in several recent years that is the latest generation in wireless communication technology. The 5G New Radio offers significantly higher the peak data range, high-frequency, and low-latency comparing to Long-Term Evolution (LTE). Both of them can be distinguished by the frequency range of spectrum extraction. In the recent year, the deep learning network domain introduced various cutting-edge approaches to tackle image processing in several applications such as the medical identify, spectrum sensing in signal processing, and automotive industry that utilize image segmentation techniques. In this paper, we propose the cutting-edge deep learning network base on Unet++ to enhance spectrum sensing for 5G New Radio (NR) and Long-Term Evolution (LTE) that incorporated by Unet++ and attention gate. In detail, we replaced traditional convolution by group convolution to reduce dramatically parameters of own network, around 50 percentage comparing with original Unet++ network, attention gates are applied into each skip connection to focus on the essential segmentation region in the small image. We utilize the spectrum of 5GNR and LTE dataset which were generated by MatLab 5G toolbox to evaluate own network, compare with other DeepLabv3++ and original Unet models. The accuracy of own network reached at XXX% that is higher than DeepLabv3++, Unet, Unet++ by xx%, yy%, zz%. Our implementation and pre-trained model are available at: Spectrum sensing base on deep learning Github project**

***Index Terms*—spectrum sensing, 5G New Radio (5G NR), Long-Term Evolution (LTE), Unet, unet++, deep learning network, attention gate, group convolution, sematic image segmentation, signal processing**

I. Introduction

The 5G New Radio (NR) is the next generation of cellular network technologies, it provides the high transmission data rage and fast transmission in kinds of different frequencies that include low-bandwidth, middle-bandwidth, and high-bandwidth [7]. In particular, low-bandwidth and middle-bandwidth are popular in many countries, 3400 to 3800 MHz in Europe, 3300 to 4990 MHz in China, 3600 MHz to 4900 MHz in Japan, 3400 MHz to 3700 MHz in Korea, and 3700 MHz to 4200 MHz in United States. The 5G NR offers the long range of frequencies than fourth Long-Term Evolution (LTE), 5G NR offers a broader spectrum range, spanning from below 1GHz up to 52.6GHz, whereas LTE typically operates within the 3.5GHz to 5GHz range.

In contemporary times, the demand for wireless communication network by utilizing the limited spectrum resource increased dramatically in the recent year, it requires a fast recognition for kinds of wireless radio to apply into minimal electronic devices. In the last decade, several solutions had been proposed to discriminate the type of spectrum in wireless communication network. The paper ”Intelligent Spectrum Sensing with ConvNet for 5G and LTE Signals Identification” [1] introduced a innovative methodology that utilizing deep learning network which is ConvNet built by incoporating DeepLabv3+ (an efficient encode-decoder architecture for pixel-level classification) and ResNet18 (as a backbone network for feature extraction). As the result, it reached outstanding results with global accuracy 75% and 95% at signal-to-noise ratio 40db and 60db respectively [1], comparing to global accuracy 78% and 97% at signal-to-noise ratio 40db and 60db, respectively that using the enhance DeepLabV3+, which was showed by ”Accurate Spectrum Sensing with Improved DeepLabV3+ for 5G-LTE Signals Identification” [2].

In the recent year, The deep learning network industry witnessed the development process of sematic segmentation, numerous robust encoder-decoder deep learning network was introduced for sematic segmentation domain that opened opportunities in image processing feild, high precision together with light weight that have ability adapt to minimal electronic devices, contributing to numberous applications related to Biomedical Image Segmentation [5], signal processing [1] [2], and medical Identification. To begin with a light wieght sematic segmentation deep learning network, Unet convolution network for Biomedical image segmentation was presented by Computer Science Department and BIOSS Center for Biological Signaling Studies, University of Freiburg, Germany in 2015 [5]. Unet was built by multiple scale convolution networks including two path encoder and decoder from high-scale to small-scale image and small-scale image to high-scale image connected to encoder path and decoder path respectively. In 2020, Unet++ is a redesigning skip connection to exploit multiple scales features in image segmentation that was presented by Zongwei Zhou [6]. Unet++ offered a higher accuracy than traditional Unet network by utilizing skip connection in each layer, the space between layers was replaced by deep convolution blocks that aim increase features extraction in the output of the network. However, these lead to increase the size of the network dramatically, the total parameters of Unet++ increased approximately fourth times comparing to traditional Unet network. [6].

In this paper, we introcduced a innovative methodology to enhance Unet++ deep learning network to tackle spectrum sensing 5G New Radio (NR) and Long-Term Evolution (LTE) base on recieved spectrum in frequency domain by the discrete fourier transform. To begin with, we utilize group convolution [9] to reduce dramatically size of the network, it not only has vital role in reducing the total of parameters but also retain a rebust accuracy. On the other hand, attention mechanism was introduce in "Attention Is All You Need" [4], which created a renovation in the deep learning domain in general and sematic image segmentaion in Specific. In particular, Attention mechanism forcus on the mainly region in the image where need to discriminate segment of objects. Therefore, attention blocks have a light weight which plays a vital role for development deep learning network in compact power device, especially in signal processing where numberous applications was deloyed in smartphones, laptops, and others to discriminate the type of recieved signals that requires minimum computing performance. Thank to attention mechainsm, attention gate mechainism was in troduced in "Attention U-Net: Learning Where to Look for the Pancreas" [3] by Biomedical Image Analysis Group, Imperial College London, London, UK in 2008, which enhance the discriminated ability of Unet network. In detail, attention gates adapted to skip connection in each layer of Unet network, it filter the features propagated through the skip connections [3]. The achievement of attention gates are forcusing on extracted features in the same size at the corresponding layer, incoporating skip connections and lower layers by concatenation. As the result, this method showed effectively sematic image segmentation in classification and regression tasks [3]. Finally, we utilized incoporated attention gates and group convolution to reduce the size of the Unet++ network and rise the accuracy through attention gates that adapted to skip connection layers to tackle spectrum sensing for the 5G New Radio (NR) and the Long-term Evolution (LTE) base on recieved spectrum signals. Our objective are present a new innovative deep learning network base on Unet++ architecture that has a minimal parameters comparing to previous Unet [5], Unet++ [6], DeepLabV3+ [2], and Convenet [1] deep learning network.

II. Methodology

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Number equations consecutively. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in:

$$a + b = \gamma \tag{1}$$

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An excellent style manual for science writers is [7].

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TABLE I
TABLE TYPE STYLES

Table Head	**Table Column Head**		
	Table column subhead	***Subhead***	***Subhead***
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[a]Sample of a Table footnote.

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Fig. 1. Example of a figure caption.

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References

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For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [6].

References

[1] Huynh-The, Thien, et al. "Intelligent Spectrum Sensing with ConvNet for 5G and LTE Signals Identification." 2023 IEEE Statistical Signal Processing Workshop (SSP). IEEE, 2023.

[2] Nguyen, Gia-Vuong, Ca Van Phan, and Thien Huynh-The. "Accurate Spectrum Sensing with Improved DeepLabV3+ for 5G-LTE Signals Identification." Proceedings of the 12th International Symposium on Information and Communication Technology. 2023.

[3] Oktay, Ozan, et al. "Attention u-net: Learning where to look for the pancreas." arXiv preprint arXiv:1804.03999 (2018).

[4] Vaswani, Ashish, et al. "Attention is all you need." Advances in neural information processing systems 30 (2017).

[5] Ronneberger, Olaf, Philipp Fischer, and Thomas Brox. "U-net: Convolutional networks for biomedical image segmentation." Medical image computing and computer-assisted intervention–MICCAI 2015: 18th international conference, Munich, Germany, October 5-9, 2015, proceedings, part III 18. Springer International Publishing, 2015.

[6] Zhou, Zongwei, et al. "Unet++: Redesigning skip connections to exploit multiscale features in image segmentation." IEEE transactions on medical imaging 39.6 (2019): 1856-1867.

[7] Pirinen, Pekka. "A brief overview of 5G research activities." 1st International Conference on 5G for Ubiquitous Connectivity. IEEE, 2014.

[8] Lin, Xingqin, and Namyoon Lee. "5G and Beyond." Cham, Switzerland: Springer Nature Switzerland AG (2021).

[9] Krizhevsky, Alex, Ilya Sutskever, and Geoffrey E. Hinton. "Imagenet classification with deep convolutional neural networks." Advances in neural information processing systems 25 (2012).

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