5G 통신 MAC 스케줄러에 관한 연구

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A Study on AI-based MAC Scheduler in Beyond 5G Communication

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Abstract

The quest for reliability in Artificial Intelligence (AI) is progressively urgent, especially in the field of next generation wireless networks. Future Beyond 5G (B5G)/6G networks will connect a huge number of devices and will offer innovative services invested with AI and Machine Learning tools. Wireless communications, in general, and medium access control (MAC) techniques were among the fields that were heavily affected by this improvement. This study presents the applications and services of future communication networks. This study details the Medium Access Control (MAC) scheduler of Beyond-5G/6G from 3rd Generation Partnership (3GPP) and highlights the current open research issues which are yet to be optimized. This study provides an overview of how AI plays an important role in improving next generation communication by solving MAC-layer issues such as resource scheduling and queueing. We will select C-V2X as our use case to implement our proposed MAC scheduling model.

Keywords: New Radio (NR), Beyond 5G/6G, Artificial Intelligence, Medium Access Control (MAC) layer, C-V2X

1. Introduction

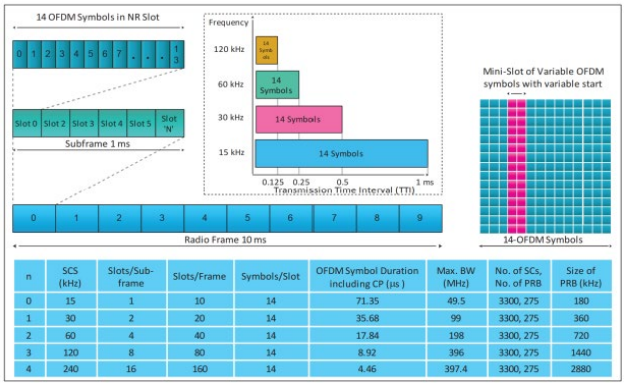
The next generation network is shifting the focus from high-data rate services like the enhanced mobile broadband (eMBB) and massive machine-type-communication (mMTC) to delay-centric ultra-reliable low latency communication (URLLC). With a 1000x increase in data rate and network capacity, the Beyond5G/6G of mobile communications was projected to be the major enabler for future network [1]. The area of wireless communications has been heavily affected by recent advances in AI-based algorithms and technologies. Specifically, AI was a main player in the 5G and beyond communication systems. AI is the main motivation of the B5G network to offer a self-organizable and self-sustainable fully autonomous network. It has been adopted to provide modern communication systems with a plethora of intelligent services and functions such as intelligent resource allocation [2], link adaptation [3], beamforming [4], channel estimation [5]. Recently, the advances in ML/DL techniques have also affected the design of medium access control (MAC) [6].

Designing an efficient MAC technique is a complicated technique and challenging problem such as collision, throughput, fairness, etc. With the expedite in development of 5G towards 6G, it becomes essential to propose MAC protocols that support different applications such as ultra-reliable low latency communications (URLLC) [7], enhanced mobile broadband [8] and massive machine-type communications [9].

The purpose of Beyond 5G is to offer seamless services, however various applications coexist in a network transmission causes disruptions. To support this B5G networks need to be capable of supporting data traffic from heterogenous (Het) devices with improved reliability, low-latency, and high data rates in uplink and downlink direction. To address this issue the 3GPP release 15 introduced frame structure and scalable numerology as shown in Fig.1. This study presents issues related to the medium access control (MAC) layer and provides insights to the solution.

Motivation: The challenges and open issues in future-generation communications are caused mainly due to the flexible MAC layer structure, operability, and scalability over a wide range of frequency bands. Furthermore, future-generation communication must support coexistence with other enabling technologies specifically IEEE 802.11 ax, ay, and upcoming future standards, operating simultaneously on the same or other frequency bands. The rising interest in ML-based MAC techniques can be clearly observed by the number of articles in this field. Therefore, a comprehensive review of the widely adopted ML/DL algorithms as well as the MAC design issues can significantly help the researchers

accelerate their work. This article highlights the open research issues and challenges in the MAC layer for future-generation networks based on AI assisted resolutions.



n	SCS (kHz)	Slots/Sub-frame	Slots/Frame	Symbols/Slot	OFDM Symbol Duration including CP (μs)	Max. BW (MHz)	No. of SCs, No. of PRB	Size of PRB (kHz)
0	15	1	10	14	71.35	49.5	3300, 275	180
1	30	2	20	14	35.68	99	3300, 275	360
2	60	4	40	14	17.84	198	3300, 275	720
3	120	8	80	14	8.92	396	3300, 275	1440
4	240	16	160	14	4.46	397.4	3300, 275	2880

2. Research Background

Wireless networks depend heavily on Radio Access Networks (RAN) to provide seamless communication access to users. However, traditional RANs reduce the versatility and intelligence required to address the dynamic requirements of users in Next Generation wireless [10]. Currently, a large number of studies have been conducted to improve the performance of MAC schedulers. In [11] propose a two-level MAC scheduler for wireless networks, classifying resource management decisions as intra-slice resource allocation and inter-slice resource mapping. We have discussed in detail the MAC Layer design issues to help understating and identifying particular issue.

2.1. MAC Layer Design Issues

There are several protocol designs proposed for addressing the medium access problem in wireless networks [12]. These issues vary from one application to another such as in VANETs, the high-speed mobility among the nodes cause frequent and fast changes in the topology. However, Wi-Fi networks have less mobility among the nodes, which also causes less topology changes. In this section, we will discuss some of the important issues that need to be addressed when designing a MAC protocol:

1) **Efficient Bandwidth Utilization:** The resource limitation in radio spectrum, bandwidth is limited. To utilize bandwidth efficiently, different methods for decreasing the overhead control should be implemented. The ratio of bandwidth used for transmission of the data to the bandwidth available is termed as bandwidth efficiency. In using more bandwidth ratio for data transmission, increasing the number is suitable for efficient bandwidth utilization.
2) **Robust Shared Broadcast Channel:** In wireless broadcast nature when a sender node transmits to a source node, then no other node should be transmitting. It is quite frequent that the medium is simultaneously accessed by nodes in the same neighborhood, therefore the chances of transmission collisions in wireless networks are very high.
3) **Nodes Mobility:** The channel access scheduling of stationary nodes is much easier than of mobile nodes. A MAC protocol design should be considered with nature of mobility and the speed of nodes, especially in Vehicular networks to provide the efficient mechanism [13].
4) **Synchronization:** To synchronize the operation of different nodes is very important in wireless networks. In distributed networks it is not so easy case as the control is shared completely and to maintain synchronization in this environment is of crucial importance. However, in centralized networks its easier because of centralized clock shared by the network infrastructure.
5) **Queueing Model:** The queueing model in next generation networks (B5G/6G) is also a very crucial research issue. The MAC layer behavior when a next generation NodeB (gNB) queues heterogenous traffic at the medium is directly impacted by scheduler. The 3GPP has defined the techniques in NR for B5G applications to fulfil the latency and reliability to enhance the Quality of Service (QoS). Queueing methods need to be robust and intelligent as it impacts the QoS of communication, therefore AI-based queueing methods need to be developed.

2.2. Artificial Intelligence to address issues in B5G MAC

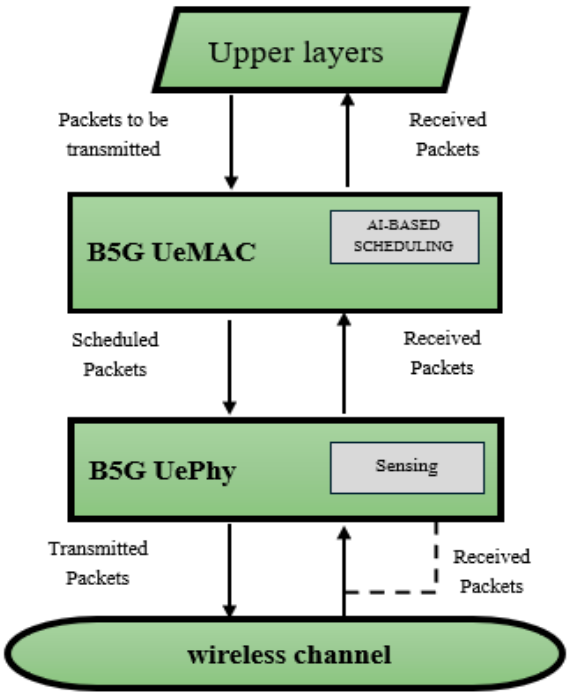
Artificial Intelligence (AI) enables machines to behave like human brain intelligence. Machine Learning (ML) and Deep Learning (DL) are subsets of AI, However Reinforcement Learning is a new paradigm of ML which is different from traditional (Supervised and unsupervised) ML algorithms. Collaboration between AI and wireless networks has been widely investigated [14] in terms of challenges and opportunities for future B5g/6G networks. The Federated Learning (FL) in wireless network has gained a significant momentum in recent days. [15] discussed some potential applications in 5G networks such as enabling dynamic access to spectrum, device nonlinearity information, and detection of abnormal signal. The successful adoption of AI techniques to the PHY, MAC and Network layers, with applications ranging from channel estimation and prediction to dynamic spectrum access and resource management and scheduling. In [16] the authors present a new TDMA-based MAC protocol, called Bitmap-assisted Efficient and Scalable Time-based MAC (BEST-MAC). The primary goal of BEST-MAC is to enhance quality control in applications for smart cities where diversified traffic is in demand and data loss, or delays are undesirable. These techniques do not deal with

scaling problems as they address only fixed problems. In highly dynamic wireless networks, MAC protocols are also required to be designed to adapt to changing conditions. In such dynamic networks, intelligent MAC schemes should be designed to adapt to changing topologies. Considering the important role of intelligent MAC model in addressing the above challenges, this paper proposes an AI-based approach for MAC layer protocol challenges.

3. Proposed Approach

In this section, we formally present our approach that aims to propose an AI-based MAC-layer model in B5G architecture. The MAC protocol behaves when a next-generation NodeB (gNB) queues heterogeneous traffic at the downlink. While the scheduler plans the first Hybrid Automatic Repeat Request (HARQ) transfer, the data packets belonging to the heterogeneous users are buffered at the gNB in the first transmission queue. A packet that cannot be decoded at the receiver after N HARQ transmissions is considered as failed transmission, which degrades the reliability.

The 3GPP defined the puncturing technique in NR to fulfill latency and reliability criteria, interrupting ongoing transmission to transmit traffic mini slots without informing User Equipment (UE). In NR by default three scheduling protocols have been proposed round robin (RR), proportional fair (PF), and the maximum rate (MR) [16]. We will propose an AI-based method to utilize the enhanced scheduling protocols as per the service requirements in Cellular- Vehicle to Everything (C-V2X). In C-V2X the performance degrades with the increase of traffic, there is no congestion control mechanism and also no feedback mechanism. Therefore, it increases the use of resources. In NR-V2X to address this problem two modes are introduced Unicast, and group cast in addition to broadcast traffic.



We will propose the artificial intelligence-based solution to make the MAC Layer scheduler efficient in V2X. There are two metrics; channel busy ratio (CBR) and channel occupancy ratio (CR) defined by 3GPP [18]. To avoid channel congestion, based on the defined metrics as stated by the 3GPP, the packet transmission rate (Tx Rate) is reduced. Since the arrival time of the message, a packet cannot be controlled as it depends on the application layer, therefore, in the case of congestion the packets are buffered and not transmitted. Therefore, the vehicle adjusts its TX Rate to reduce the channel congestion. However, this may increase the latency associated with the generated packets, since the packets are buffered and not transmitted.

To address this issue, we will propose a gNB act as a source which schedules the resources intelligently for the UEs. The gNB assigns the radio resource block to the subset of the UEs which have data in their buffer to send and it is not associated with the HARQ. The researchers have evaluated the sub 6 Hz band for V2X, however, the research is open for the exploitation of the mmWaves band also.

3.1. Proposed System Model

The AI-based MAC scheduler system model performs the scheduling process based on dynamic traffic requirements the QoS MAC scheduler needs to perform intelligent. Fig. 2 shows the block diagram of the MAC and PHY layers of the C-V2X simulator. At the PHY layer (LteUe Phy), we will add a AI-based sensing module that measures the signal strengths of all received packets on the corresponding resource blocks and stores this data in the sensing data structure. This data structure keeps the measured signal strength of the latest subframes, according to the sensing window. For each new subframe, the new data is stored, and the oldest sensing data discarded. The AI-based MAC scheduler module is implemented in the MAC layer (B5GUe Mac). It uses the sensing data structure as an input to determine the resource allocation. The new design of the proposed MAC scheduler is based on the selection of scheduling weights. Without losing generalization to other types of traffic and in order to meet the strict requirements imposed by the inherent time-critical nature of the C-V2X.

applications, such as the low latency

3.2. Tools and Simulators

The 3GPP introduced NR in Release 15 and provided many papers that evaluated results along with it. However, the evaluating simulators are not made publicly available. Moreover, most private simulators are licensed and require heavy fees. T. The CTTC-Lena group has designed an NR simulator based on Network Simulator-III (NS3) named 5G-Lena NR, which is an open-source platform [19]. The 5G-Lena NR is licensed under the system-level simulation and can be carried out using Vienna simulator [20]. The simulator is designed in a modular manner and is based on MATLAB to support different features. The simulator attracts researchers working in the field of Physical and MAC layers. On the other hand, MATLAB provides the 5G toolbox and supports freedom of modification as well.

4. Conclusion

Over the past decade, there has been a marked advancement in the field of Machine Learning (ML) and Deep Learning (DL) techniques. These developments have had a significant impact on a wide range of industries. In the realm of wireless communications, the utilization of ML techniques has been implemented to enhance various Medium Access Control (MAC) Layers. In this work, we have proposed a novel method for AI-based MAC Layer Scheduler. Our method is envisioned to empower B5G/6G networks with AI services and stems from the urge for reduced latency and reliability in intelligent systems. We will use the 5G-LENA simulator in order to validate the correct operation of the scheduler in C-V2X scenario. Moreover, we will carry out the performance evaluation in multiple environments and will compare against traditional schedulers.

This work is a preliminary study for more complex C-V2X scenarios and paves the way for various scheduling approaches to be evaluated. In future, our vision is to perform E2E system-level evaluations of the proposed AI-based MAC scheduler for C-V2X.

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