International Journal of Computational and Experimental Science and ENgineering (IJCESEN)

Vol. 11-No.2 (2025) pp. 2887-2895
http://www.ijcesen.com

ISSN: 2149-9144

Research Article

A Performance analysis of downlink scheduling algorithms under SCWI and SCWF scenarios for 5G/6G communication networks

Pardeep Kumar[1]*, Parvinder Singh[2]

[1] Department of CSE, Deenbandhu Chhotu Ram University of Science & Technology, Murthal, Sonipat (Haryana)
* **Corresponding Author Email:** er.pardeepawasthi@gmail.com - **ORCID:** 0009-0003-0077-4268

[2] Department of CSE, Deenbandhu Chhotu Ram University of Science & Technology, Murthal, Sonipat (Haryana)
Email: parvindersingh.cse@dcrustm.org - **ORCID:** 0000-0001-6741-9859

Article Info:

DOI: 10.22399/ijcesen.952
Received : 25 February 2025
Accepted : 30 April 2025

Keywords

Resource Scheduling
MTC
5G
6G
LOG_RULE
MT

Abstract:

Fifth-generation wireless technology, or 5G, is the most recent mobile telecommunications standard. With higher data speeds, reduced latency, more capacity, and better connectivity than its forerunner, 4G, it represents a considerable improvement. In 5G networks, the scheduling mechanism regulates how much data is sent between different devices and the network. Cellular networks are really used in a variety of situations, including dense (urban regions), non-dense (rural areas), ultra-dense, etc. Schedulers are formed over the base stations to effectively allocate resources to the cell's customers. These schedulers operate according to the circumstances in which they are employed. Two scenarios—Single-Cell with Interference and Single-Cell with Femto-Cell—are developed in this paper by editing the code. The defined scenarios are then implemented using the two existing schedulers: Log_Rule and Maximum Throughput (MT). These approaches are applied to the aforementioned conditions, and the results are measured in terms of throughput, packet loss ratio, latency, and spectrum efficiency.

1. Introduction

5G, short for "fifth generation," is the most recent and sophisticated version of wireless communication technology. It provides a major improvement over 4G LTE (Long-Term Evolution), its predecessor. Because it offers faster data rates, reduced latency, more capacity, and higher dependability for both consumer and industrial applications, 5G was created to address the ever-growing demands of modern communication. [1,9]

Applications of 5G

- Massive Machine-Type Communications (MTC): Massive connections between low-power, low-data-rate devices are supported by 5G. Applications for these gadgets include the Internet of Things (IoT), smart agriculture, and smart cities. [11]
- Ultra-Reliable Low Latency Communications (URLLC): With its improved dependability, 5G is appropriate for mission-critical services like remote surgery, industrial automation, and public safety, which require a constant connection. [11]
- Enhanced Mobile Broadband (eMBB): 5G offers a more smooth and complete mobile experience by offering faster data speeds and increased network capacity. This makes it possible to broadcast high-definition 4K and 8K videos and use augmented reality and virtual reality apps. [11]

Features of 5G

- Increased Speed: Faster data transmission speeds are one of 5G's most noticeable benefits. It can achieve peak upload and download rates of up to 10 and 20 gigabits per second (Gbps), respectively. Users may browse the internet more rapidly and download huge files and high-definition films with ease because of this fast speed. [2]

- Low Latency: The amount of time it takes for data to travel between devices and servers is called latency, and it is greatly reduced with 5G. With 5G, latency can be significantly lower, down to one millisecond (ms). For real-time applications like online gaming, augmented reality (AR), virtual reality (VR), and autonomous cars, where immediate reactions are crucial, this reduction in latency is crucial. [3]
- Greater Capacity: In comparison to earlier generations, 5G can support more connected devices in a given region at once. This increased capacity is essential in congested metropolitan areas or at gatherings with a sizable throng of visitors. [11]

In addition to the conventional cellular spectrum, 5G makes use of higher frequency radio waves, such as millimeter waves (mm-wave), to achieve these improvements. However, because of their limited range and potential for interference, higher-frequency waves require additional infrastructure, including more small cells and antennas. It's crucial to remember that 5G rollout is a continuous process, and the availability of the technology may vary based on the location and the state of the infrastructure. It is anticipated that 5G will revolutionize several sectors and spur technological and communications innovation as it continues to roll out and proliferate. [3,4]

Resource Allocation

The act of choosing when and how the base station, sometimes referred to as the gNB or gNodeB, delivers data to the user equipment (UE), such as smartphones or other devices, is referred to as downlink scheduling in 5G networks. Downlink scheduling is to optimally distribute radio resources and deliver optimal data transmission to numerous UEs while taking into account variables including channel circumstances, needs for the quality of service, and user fairness. Here is how 5G's downlink scheduling functions. [7,8,11]

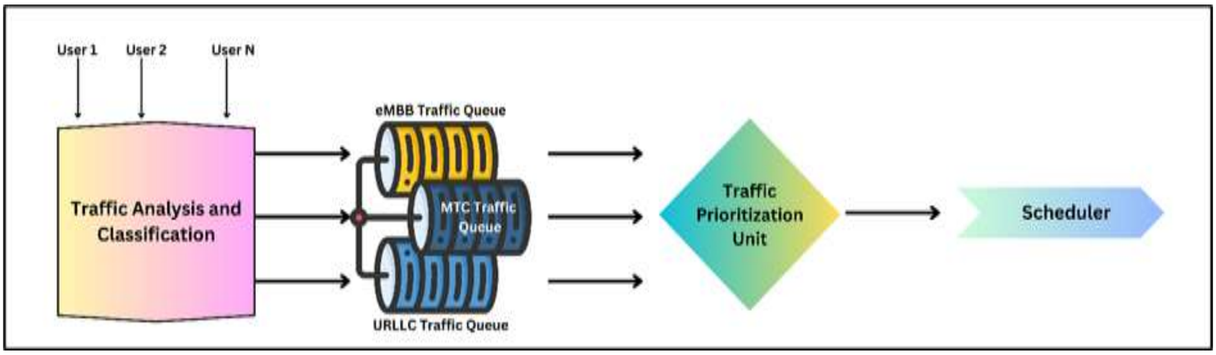

Figure 1. *Traffic classification and prioritization before scheduling*

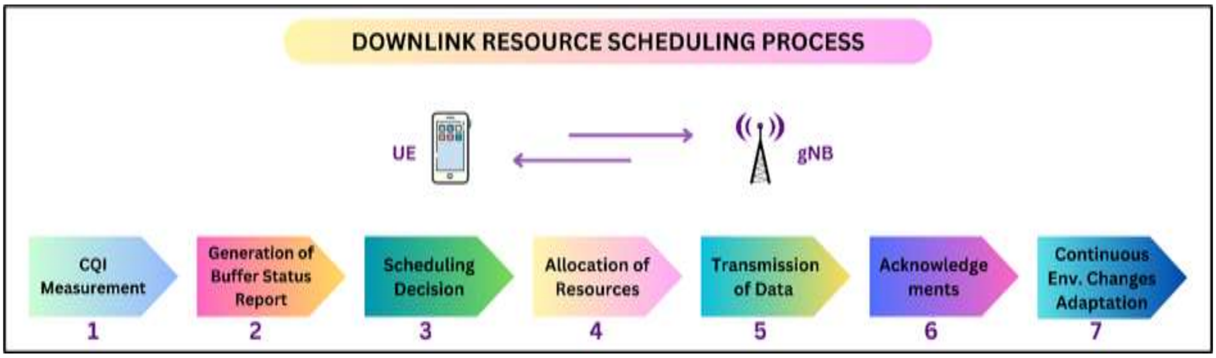

Figure 2. *The downlink scheduling procedure*

2. Related Work

Mamode et. al. [6] reviewed the 5G network architecture in detail, existing scheduling algorithms that are already implemented in 5th-generation mobile communication technology, and some proposed scheduling algorithms by different researchers based upon the different parameters. The proposed algorithms are studied in such a way that the reader can easily identify the core concepts of the schedulers and their implementations. Finally, the scheduling algorithms are examined and the author enlightens the new roadmaps for the future and what enhancements can be made in the future.

Mustaffa et. al. [7] presented a review of those scheduling algorithms that are designed to improve cell edge performance. Because the normal scheduler works on behalf of equality, they provide their 100% to all the users existing in the cell. But due to so many factors like Inter-Cell Interference, SINR (Signal-to-Noise Ratio), etc., the users who are residing at the cell edge do not get 100% of the resources. So, the drawback of this seems like call drop, more delay, less spectral efficiency, more packet loss ratio, and many more. To overcome these hurdles for the cell edge users the new scheduling approaches are proposed by the researchers which gives more attention to cell edge users to increase their performance. In this paper, the authors studied the papers which are presented after 2015. The approaches like Cooperative Transmission Scheme, Packet Scheduling, Soft Frequency Reuse, and Downlink Optimal Power Allocation Scheme which emphasize the cell edge performance improvement are taken into account.
Pardana et. al. [8] carried out a comparative study of the round-robin (RR) and Proportional Fair (PF) scheduling algorithms using NS-3 for different UE density scenarios using Voice and Video traffic for the evaluation of performance impact on 5G mm-wave networks. On the behalf of obtained results, they found the Round Robin (RR) algorithm is best suited for voice traffic. RR provides good throughput as compared to the PF algorithm but the fairness index for both is approximately similar. On the other hand, they found PF is suitable for Video traffic because it provides high throughput as compared to RR.
Kumar et. al. [11] analyzed the performance of different downlink scheduling algorithms namely Proportional Fair (PF), Modified Least Weighted Delay First (M-LWDF), Exponential Proportional Fair (EXPF), and FLS (Frame Level Schedular) on an interfered cell scenario with the consideration of different data flows like VIDEO, VOIP, CBR, etc. This simulation was done on LTE release 5 with a set of parameters like frequency, cell radius, no of users per cell, mobility speed of the users, duplexing scheme (TDD) is considered here, etc. Finally, it is concluded that MLDWF and EXP-PF gave better spectral efficiency with an increase in the number of users. On the other side, PF is not an appropriate algorithm for video flow due to high packet loss, higher delay, low fairness index, and lower throughput. The remaining three EXP-PF, FLS, and MLWDF are appropriate for video flow. For Best Effort flow, all the scheduling algorithms give the same performance. The PF, EXP-PF, and MLWDF are appropriate algorithms for CBR flow but FLS is not good due to more packet loss, more delay, and low overall throughput.

Implemented Schedulers

In this article, SCWI and SCWF situations are handled by two schedulers, Log_Rule and Maximum Throughput (MT). The following is a summary of the schedulers who are currently employed.

Log_Rule

A delay-sensitive method that enables both real-time and non-real-time data transfer is the Log_Rule method. This method strongly emphasizes equitable resource distribution and increased system throughput. Due to the fact that this is a real-time data scheduler, it performs better with video and other real-time data flow. [10,14]
Maximum Throughput
Maximum Throughput (MT) scheduling algorithms aim to maximize system throughput without considering individual user performance. Equitable distribution among users is not ensured by this algorithm. The algorithm picks a user in each assignment interval who maximizes the metrics listed below: [10, 15]
As a result, a user with a bad channel position has a lesser chance of transmitting. This technique may not schedule a user at all if they frequently have bad channel conditions, which might reduce system throughput as a whole. It is a scheduling algorithm that is aware of channels but not of the quality of service. The algorithm operates at its best when all consumers have reasonably acceptable channel conditions.

Table 1. *Matrices for the algorithms*

Ref	**Algorithm**	**Matric**
[15]	Log_Rule	$S_{i,t}^{LogRule}$ = arg max$_i$ $b_i$log (c+$a_i D_i^{H,L}$)K_i
[15]	Maximum Throughput	$S_{i,t}^{MT}$ = arg max r_i (t)i

3. Simulation Environment

This article uses code modification to create two distinct scenarios, Single Cell with Interference (SCWI) and Single Cell with Femto (SCWF). The SCWI scenario is created by assigning the same set of channels (in this case, X set of channels) to every cell in the cluster. Because the same frequency band among the cells is being used without taking the frequency reuse distance (D) into consideration, interference will result in this circumstance. The simulation is then performed using Cell 1. The second scenario, known as SCWF, on the other hand, is designed for a single cell with a connected femtocell for a unique zone in order to provide connection to the users of the unique area. Then, the two currently used scheduling algorithms, Log_Rule and Maximum Throughput (MT), are employed. The schedulers are tested for various data flows, including VoIP, video, and CBR. Then, given the planned scenario, the final results of these schedulers are evaluated using several matrices, including Packet Loss Ratio (PLR), Spectral Efficiency, and Throughput. The whole simulation environment was built using the "5G Air Simulator" open-source tool. The Ubuntu operating system has the 5G air simulator installed. Finally, Microsoft Excel 2021 is used to create the outcome graphs. The SCWI and SCWF situations are shown in Figures 3 and 4, respectively.

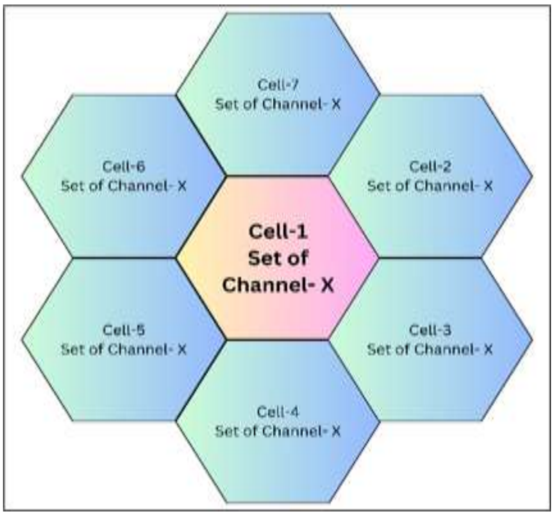

Figure 3. *Single Cell with Interference (SCWI)*

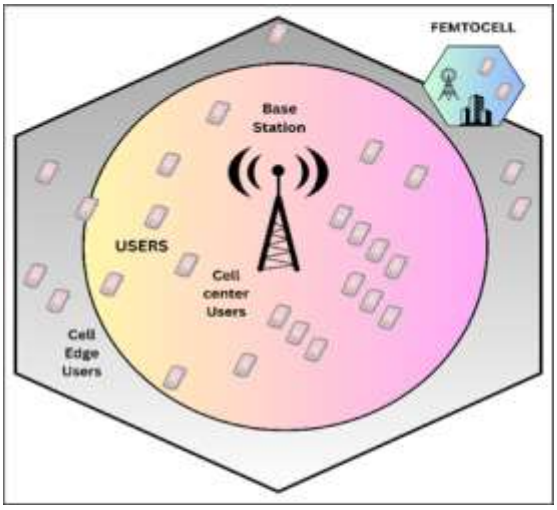

Figure 4. *Single Cell with Femto (SCWF)*

Simulation Parameters:

Packet Loss Ratio: A networking statistic known as the packet loss ratio (PLR) calculates the percentage of data packets that are dropped or lost during transit between two network nodes. Data is sent through computer networks in the form of tiny units called packets. These packets, which include data including text, graphics, music, and video, go through numerous network components and connections before arriving at their final destination. Network congestion, hardware problems, software bugs, or problems with the network infrastructure are only a few causes of packet loss. The receiving device does not get all of the data when a packet is lost, which can result in data corruption or service disruption. The Packet Loss Ratio is determined by dividing the total number of transmitted and received packets by the number of lost packets, and is commonly stated as a percentage or a fraction:

*PLR= (Number of Lost Packets / Total Packets) * 100* (1)

A network connection that has a low packet loss ratio is preferable since it is dependable and steady. Higher packet loss can lead to slower data transfers, decreased network performance, and interruptions in real-time activities like online gaming or video conferencing. PLR monitoring is an aspect of network performance management and troubleshooting that network managers use to find and fix problems that might be causing packet loss.

Spectral Efficiency: In wireless communication systems, a critical performance parameter called spectral efficiency is used to assess how well the available frequency spectrum is being used to convey data or information. It determines how much information may be safely delivered over a specific bandwidth or frequency range.

The radio frequency spectrum is a valuable and finite resource in wireless communication. The capacity and data rates that may be obtained in a wireless network are directly impacted by spectral efficiency, making it essential. Greater spectral efficiency allows for the transmission of more data over the same bandwidth, enhancing data throughput and overall network performance.

Bits per second per Hertz (bps/Hz),
or
bits per second per Hertz per cell (bps/Hz/cell)

(2)

It displays the data rate attained for every cell or unit of frequency bandwidth.

Throughput: In the context of networking and data transfer, throughput refers to the speed at which data is effectively transported through a network from one point to another within a predetermined amount of time. It calculates the real data transmission rate while accounting for a number of variables including latency, packet loss, and network congestion.

$$Throughput = \text{Bits per second (bps)} \quad (3)$$

Parameters Table for Simulation

Table 2. *SCWI Scenario Parameter List*

Parameters	Parameters Values
Cluster	One
Cluster Size	Seven
Allocated Bandwidth	20 Mbps
Cell used for the simulation	One (Cell-1)
Starting with no of users	Four
Interval	Four
Maximum users	Thirty-Two
Radius	3 Kilometers
Stream Video	One
CBR Flow	One
Stream VoIP	One
FST	Frequency Division Duplexing
Users' mobility speed	2 KM/H
Delay	0.1
Bit rate for Video Stream	256 Kbps
Implemented Schedulers	Log_Rule, MT

Table 3. *SCWF Scenario Parameter List*

Parameters	Parameters Values
No. of Cluster	1
No of FEMTO Cell	1
Carrier Frequency	2 GHz
Bandwidth	20 Mbps
Cell	1
Cell Radius	3 KM
No of Buildings	1
Building Type	0
Activity Ratio	1
Start UE's	4
Interval among UE's	4
Maximum UE's	32
No of FEMTO UE's	5
VIDEO Flow	1
VoIP Flow	1
CBR Flow	1
FST	Frequency Div. Duplexing
Mobility Speed	2 KM/H
Max Latency	0.1
VBR (Video Bit Rate)	128 Kbps
Simulation time frame/period	46s
Flow period	40s

4. Results and Discussion

In this portion of the article, the scheduling algorithms Log_Rule and Maximum Throughput (MT) are compared for both the Single Cell with Interference (SCWI) and Single Cell with Femto (SCWF) situations. The comparison results are presented as bar graphs. The metrics utilized to contrast the results are throughput, packet loss ratio (PLR), and spectral efficiency (SE). The details of these graphs are explained in more depth below.

Packet Loss Ratio (Video Flow): Figures 5 and 6 display the outcomes of the Log_Rule and MT algorithms in terms of PLR. The graph shows that Single Cell with Interference (SCWI) achieves higher PLR than Single Cell with Femto (SCWF) for both the Log Rule and MT algorithms. Therefore, in the Single Cell with Femto (SCWF) scenario, the Log_Rule and MT are working as intended.

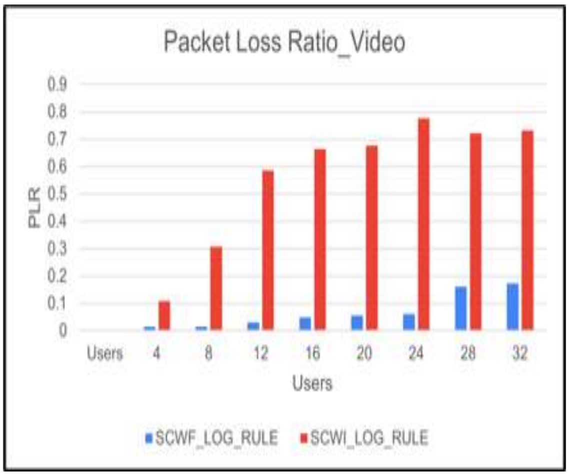

Figure 5. *Packet Loss Ratio (Video Flow) for Log_Rule algorithm*

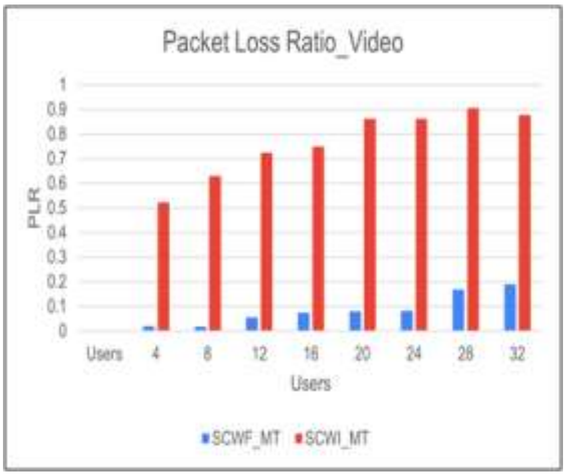

Figure 6. *Packet Loss Ratio (Video Flow) for MT algorithm*

Packet Loss Ratio (VOIP Flow): Figures 7 and 8 display the results for the VoIP data flow's packet loss ratio. The graphs were examined, and it was found that in the SCWF scenario, the MT and Log_Rule algorithms yielded less PLR than in the SCWI scenario. As a result, it can be concluded that in terms of PLR, the SCWF condition is favorable for both Log_Rule and MT.

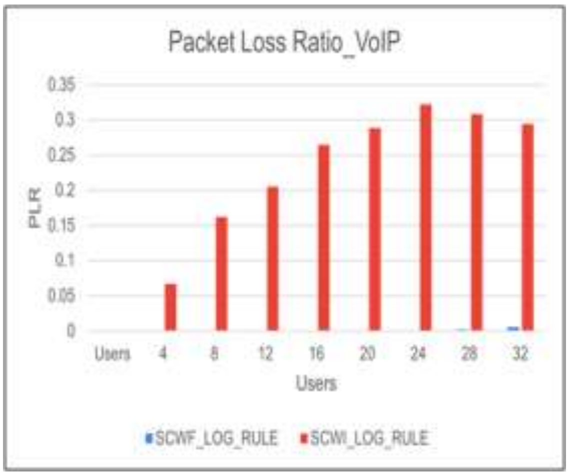

Figure 7. *Packet Loss Ratio (VoIP Flow) for Log_Rule algorithm*

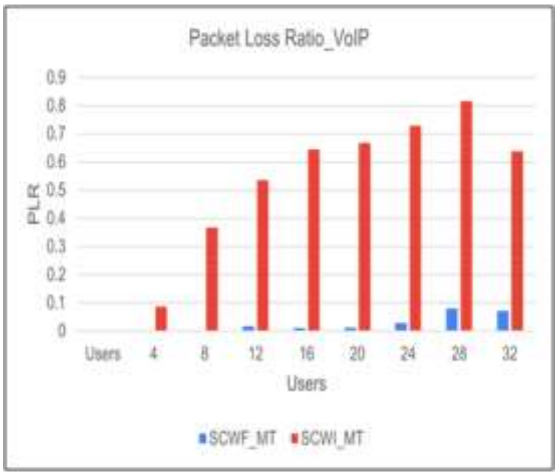

Figure 8. *Packet Loss Ratio (VoIP Flow) for MT algorithm*

Packet Loss Ratio (CBR Flow): Figures 9 and 10 provide the results for the packet loss ratio for the CBR data flow. The graphs were examined, and it was found that in the SCWF scenario, the MT and Log_Rule algorithms yielded less PLR than in the SCWI scenario. Therefore, it can be claimed that both Log_Rule and MT are doing well in the SCWF condition in terms of PLR (CBR).

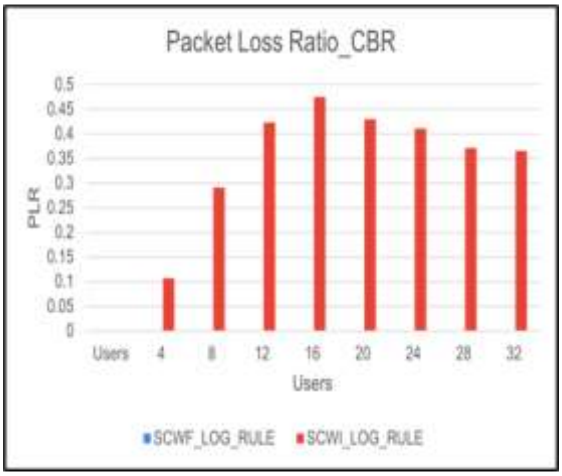

Figure 9. *Packet Loss Ratio (CBR Flow) for Log_Rule algorithm*

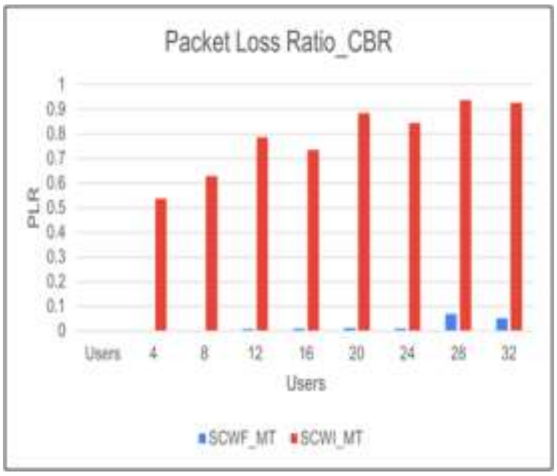

Figure 10. *Packet Loss Ratio (CBR Flow) for Log_Rule algorithm*

Spectral Efficiency: The second parameter in this study is spectral efficiency. The spectral efficiency provides information on both how well users are using the available bandwidth and how effectively the algorithms are allocating resource blocks. Figures 11 and 12's graphs demonstrate that, in the SCWF situation as opposed to the SCWI, both Log_Rule and MT algorithms produce great spectral efficiency.

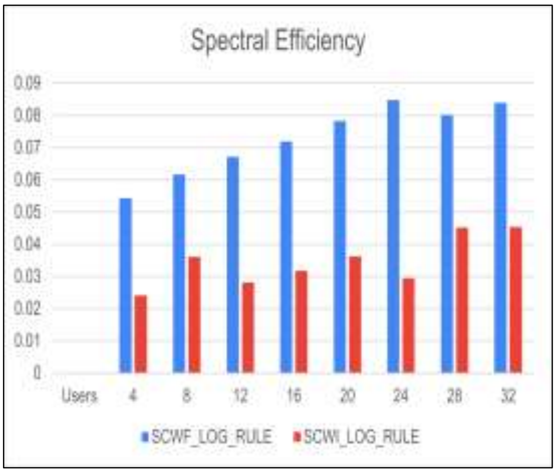

Figure 11. *Spectral Efficiency (Video, VoIP & CBR Flow) for Log_Rule algorithm*

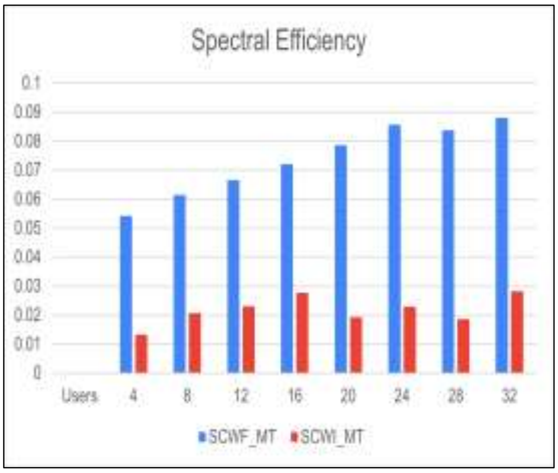

Figure 12. *Spectral Efficiency (Video, VoIP & CBR Flow) for MT algorithm*

Throughput (Video Flow): The third parameter in this study is throughput. Figures 13 and 14 provide the results for the throughput of the video data flow. The graphs were examined, and it was found that the MT and Log_Rule algorithms performed better in the SCWF scenario than in the SCWI scenario. As a result, it can be claimed that in the SCWF condition, both Log_Rule and MT are doing well in terms of throughput.

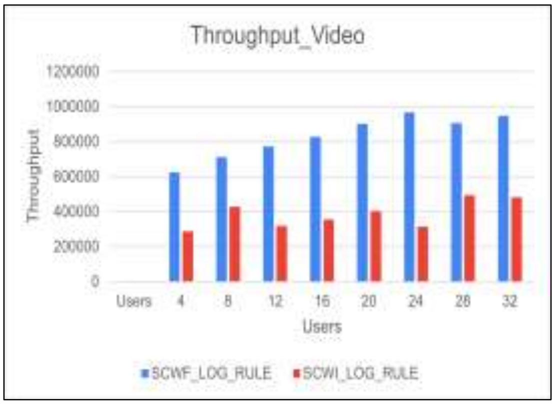

Figure 13. *Throughput (Video Flow) for Log_Rule algorithm*

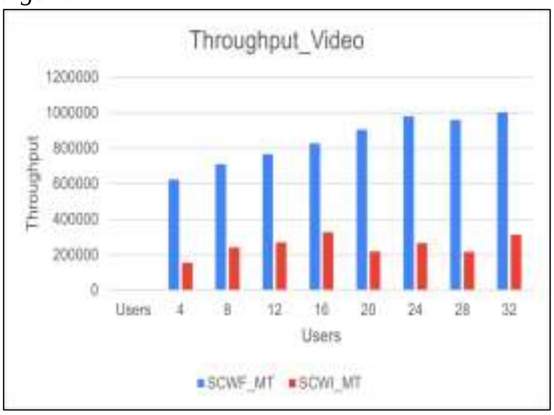

Figure 14. *Throughput (Video Flow) for MT algorithm*

Throughput (VoIP): Figures 15 and 16 provide the results for the VoIP data flow throughput. The MT and Log_Rule algorithms produced far better throughput in the SCWF scenario than in the SCWI scenario, as was found after analyzing the graphs. As a result, it can be concluded that in terms of PLR, the SCWF condition is favorable for both Log_Rule and MT.

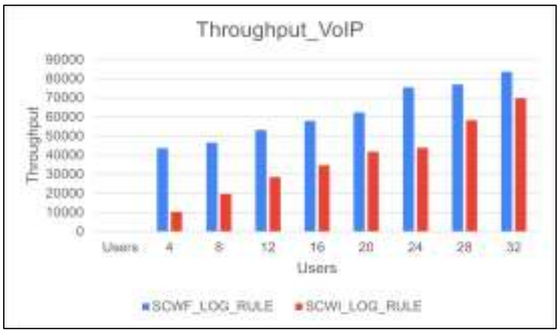

Figure 15. *Throughput (VoIP Flow) for Log_Rule algorithm*

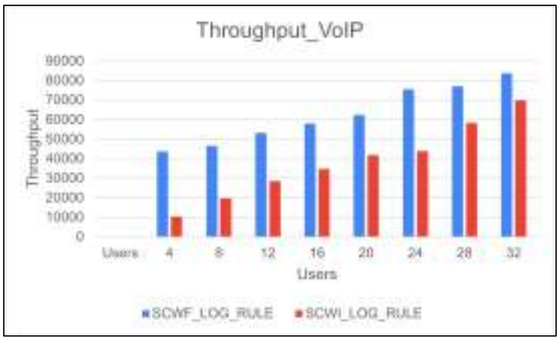

Figure 16. *Throughput (VoIP Flow) for MT algorithm*

Throughput (CBR): The findings for the throughput for the CBR data flow are shown in Figures 17 and 18. The graphs were studied, and it was discovered that the MT and Log_Rule algorithms produced significantly better throughput in the SCWF scenario than in the SCWI situation. Therefore, it can be said that in terms of throughput, Log_Rule and MT are both doing well under the SCWF scenario.

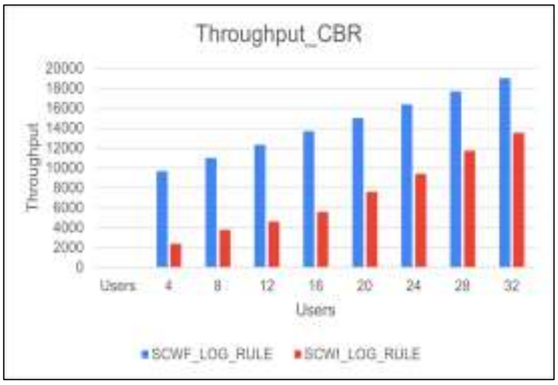

Figure 17. Throughput (CBR Flow) for Log_Rule algorithm

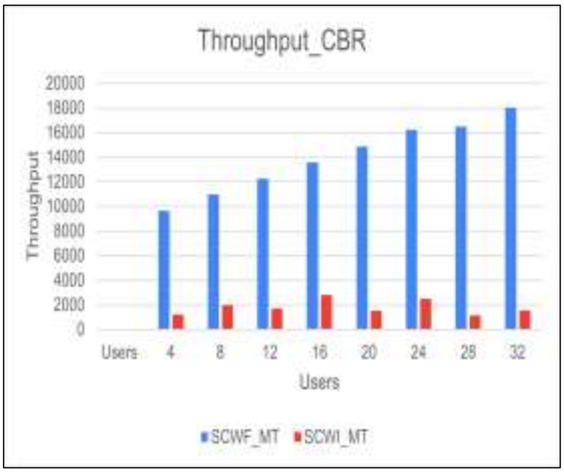

Figure 18. Throughput (CBR Flow) for MT algorithm

4. Conclusion

By modifying the code, the two situations in this article—Single-Cell with Interference and Single-Cell with Femto-Cell—are created. The results are measured in terms of throughput, packet loss ratio, and spectrum efficiency over the scenarios using two current schedulers: Log_Rule and Maximum Throughput (MT). After carefully examining each of the resulting graphs, it can be said that both schedulers perform well in the SCWF scenario as opposed to the SCWI scenario. These findings indicate that if the Frequency Reuse Distance (D) and SINR are not taken into account, the network's performance may suffer.

Future Scope

The primary objective of carrying out this comparative analysis is to investigate which algorithm possesses superior performance for the 5G network in comparison to the various network models. In an effort to make these scheduling algorithms suitable for the next generation of networks, researchers are working to enhance their capabilities that are already available.

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

- **Acknowledgement:** The authors declare that they have nobody or no-company to acknowledge.

- **Author contributions:** The authors declare that they have equal right on this paper.

- **Funding information:** The authors declare that there is no funding to be acknowledged.

- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

References

[1] Shuvo, M. S. A., Hossain, M. M., Hasan, K. M., Ahmed, R., & Rahman, M. M. (2021). Energy-efficient scheduling of small cells in 5G: A meta-heuristic approach. *Journal of Network and Computer Applications, 178*, 102986. https://doi.org/10.1016/j.jnca.2021.102986

[2] Li, L., Shao, W., & Zhou, X. (2021). A flexible scheduling algorithm for the 5th-generation networks. *Intelligent Convergence Network, 2*(2), 101–107. https://doi.org/10.23919/ICN.2020.0017

[3] Afifi, W., El-Moursy, A., Saad, M., Nassar, S., & El-Hennawy, H. (2020). A novel scheduling technique for improving cell-edge performance in 4G/5G systems. *Ain Shams Engineering Journal, 12*. https://doi.org/10.1016/j.asej.2020.07.022

[4] Ramli, H., Hashim, A., Rasied, T., Asnawi, A. L., & Rahman, F. (2022). A study of an efficient scheduling algorithm for simultaneous 5G multimedia traffic (p. 118). https://doi.org/10.1109/ICONDA56696.2022.10000347

[5] Abreu, R. B., Pocovi, G., Jacobsen, T. H., Centenaro, M., Pedersen, K. I., & Kolding, T. E. (2020). Scheduling enhancements and performance evaluation of downlink 5G time-sensitive communications. *IEEE Access, 8*, 128106–128115. https://doi.org/10.1109/ACCESS.2020.3008598

[6] Mamode, M. I. S., & Fowdur, T. P. (2020). Survey of scheduling schemes in 5G mobile communication systems. *Journal of Electrical Engineering, Electronics, Control and Computer Science, 6*(2), Article 2.

[7] Mustaffa, N. (2020). A review on techniques to improve the cell edge performance for wireless networks. *International Journal of Advanced Trends in Computer Science and Engineering, 9*, 592–600. https://doi.org/10.30534/ijatcse/2020/8291.42020

[8] Perdana, D., Sanyoto, A., & Bisono, Y. (2019). Performance evaluation and comparison of scheduling algorithms on 5G networks using network simulator. *International Journal of Computers Communications & Control, 14*, 530–539. https://doi.org/10.15837/ijccc.2019.4.3570

[9] Kumar, A., & Gupta, M. (2018). A review on activities of fifth generation mobile communication system. *Alexandria Engineering Journal, 57*(2),

1125–1135. https://doi.org/10.1016/j.aej.2017.01.043

[10] Femenias, G., Riera-Palou, F., Mestre, X., & Olmos, J. J. (2017). Downlink scheduling and resource allocation for 5G MIMO-Multicarrier: OFDM vs FBMC/OQAM. *IEEE Access, 5*, 13770–13786. https://doi.org/10.1109/ACCESS.2017.2729599

[11] Kumar, P., Kumar, S., & Dabas, C. (2016). Comparative analysis of downlink scheduling algorithms for a cell affected by interference in LTE network. *Annals of Data Science, 3*. https://doi.org/10.1007/s40745-016-0076-x

[12] Kela, P., Turkka, J., & Costa, M. (2015). Borderless mobility in 5G outdoor ultra-dense networks. *IEEE Access, 3*, 1462–1476. https://doi.org/10.1109/ACCESS.2015.2470532

[13] Singh, R., Singh, P., & Duhan, M. (2014). An effective implementation of security based algorithmic approach in mobile adhoc networks. *Human-centric Computing and Information Sciences, 4*, 7. https://doi.org/10.1186/s13673-014-0007-9

[14] Sadiq, B., Madan, R., & Sampath, A. (2009). Downlink scheduling for multiclass traffic in LTE. *EURASIP Journal on Wireless Communications and Networking, 2009*, 1–18.

[15] Haque, M. E., Tariq, F., Khandaker, M. R. A., Wong, K. K., & Zhang, Y. (2023). A survey of scheduling in 5G URLLC and outlook for emerging 6G systems. *IEEE Access, 11*, 34372–34396. https://doi.org/10.1109/ACCESS.2023.3264592