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Comparative Analysis of Max-Throughput and Proportional Fair Scheduling Algorithms in 5G Networks

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Abstrak−Mobile network service use is growing, especially after the Covid-19 pandemic. To improve the quality of mobile network services, 5G comes as a network service ecosystem with low latency, which is 1ms, or about 10 times lower than 4G, making 5G able to provide more efficient access, especially in real-time network utilization. Maximum speed can be obtained by sharing limited bandwidth. The limited amount of available bandwidth causes the need for a Packet Scheduler, which aims to improve the efficiency and fairness of bandwidth usage. This research uses two packet schedulers comparing the Proportional Fair algorithm and the Max-Throughput algorithm using test scenarios for changes in the number of users and user speed. The resulting output value analyzes resource limits such as frequency, power, speed, and time in each scenario to allocate resources so that their use remains efficient with a Quality of Service that remains stable and maintained. In simulation testing using the 5G-air-simulator, the average value obtained in the delay is 1,394 ms, throughput is 0,636, and fairness index is 0,967.

Keywords: Packet Scheduler; Proportional Fair; Max-Throughput; Quality of Service; 5g Air-Simulator.

1. INTRODUCTION

Communication technology in cellular services significantly impacts people's lives, especially in the current situation after the COVID-19 pandemic, which initially made people do WFO (work from the office) but turned into WFH (work from home), with this activity scheme indirectly causing increased network usage[1]. Service providers must optimize their infrastructure to prepare for the growing demand for large-scale data services and the increasingly necessary implementation of new 5G network technology[2]. The 5G network is an evolution of the 4G LTE (long-term evolution) network[3]. The 5G network is a new standard prepared to provide services for various network devices that continue to grow and can communicate with each other[4].

5G networks can achieve data transfer rates of up to 20 Gbps, which is faster than 4G networks with a maximum of 1 Gbps[5], capable of providing downlink and uplink services of 50-100 Mbps and a larger bandwidth of 180 kHz. One of the main design concepts of 5G networks is to adapt various access networks into one core network or Backbone to process large amounts of data so that users can enjoy better network quality on 5G networks[6]

In a study[7] by Budiman et al., the researchers grouped the analysis review using quality of service: Throughput, Delay, packet loss, and jitter. The bandwidth measurement results show poor results that require an increase in capacity because the total network bandwidth is only 20 Mbps. The total value of the Internet service quality index at SMKN 7 Jakarta is 2.14, with a medium category.

In research [8] by Perdana et al., Researchers compared the Round-Robin and Proportional Fair algorithms on NS3.27. Used in the simulation results obtained with VoIP traffic, the delay on the Round Robin algorithm shows an average of 1,215 ms. With 1,487 ms slower, 18.29% compared to Proportional Fair. These results show that the Round Robin algorithm is better than the Proportional Fair algorithm in terms of performance and is a better scheduler choice for voice traffic.

In research conducted by Hanyi, Zhang, and Su Xin, research Proportional Fair and Modified Largest Weighted Delay First (M-LWDF) algorithms are used to ensure Quality of Service and balance fairness between users on broadband WMAN networks. Simulation results show that compared to the M-LWDF algorithm. His proposed algorithm is superior in queuing delay performance and fairness while ensuring system Throughput[9].

In 2021, research was conducted by Asmae Mamane with research analysis supported by using Quality of service. The Proportional Fair (PF) scheduling algorithm is proposed for its ability to provide a tradeoff between throughput and fairness index. With buffer status coupled with Proportional Fair (PF) metrics for a new efficient scheduling algorithm to support eMBB, it is expected to propose a new scheduling algorithm that increases the experienced data rate to meet the requirements of 5G eMBB networks for dense urban scenarios[10]

In 2022 research conducted by Kautsar et al., Quality Of Service analysis of the network in Purwodadi Botanical Garden was carried out using the Wireshark tool, and quality of service parameters, namely throughput, packet loss, delay, and jitter. The simulation results show that the Quality of Service measurement obtained a throughput of 127.7146 bps, packet loss of 0.0865%, delay of 0.0125 ms, and jitter of 0.0075[11].

Previous research has proven that using a Packet Scheduler significantly affects the performance of 5G networks. This research compares Packet Scheduler algorithms, Proportional Fair and Max-Throughput, and analyzes Quality of Service performance parameters such as delay, throughput, and fairness index. Thus, this

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research is conducted by considering the suitability of delay for each user (UE) concerning throughput limitations in 5G networks to be ready for use.

2. RESEARCH METHODOLOGY

2.1 Research Stages

The simulations in this study were conducted on a 5G-Air-Simulator designed to implement multiple network architectures with numerous cells and users, different mobility, and application models.

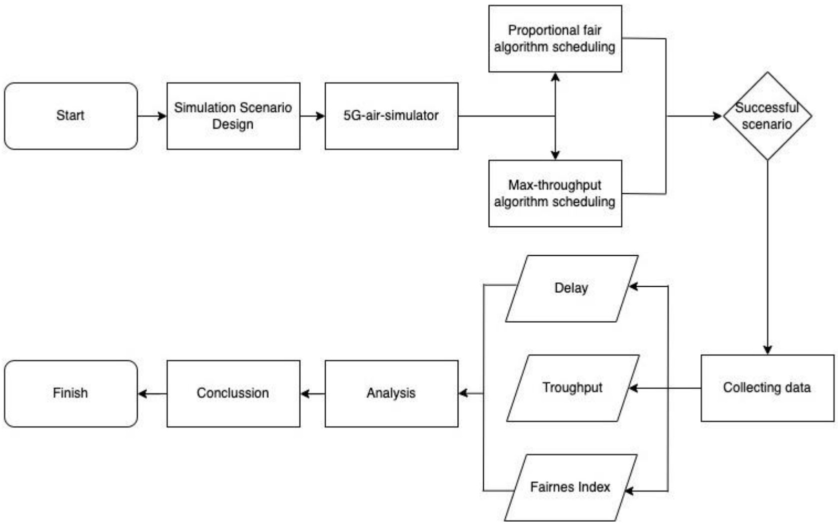

Figure 1. System Design

Figure 1 shows the research flow. First, the simulation design uses a test scenario using 5G-Air-Simulators with two packet scheduler comparisons, namely the Proportional Fair algorithm and the Max-Throughput algorithm. Then the data results are then used to measure the Quality of Service parameters such as delay, throughput, and fairness index. In the last stage, the data results and measurement values will be analyzed to see the Quality of Service aspects.

2.2 Test Scenario Design

Scenarios are conducted to measure the Quality of Service and functionality in the form of changes or conditions to verify appropriate results. Each user will generate service traffic by comparing each flow simultaneously for 100 seconds according to the simulation used in the 5G-Air-Simulator. The service traffic will provide output values consisting of a delay, throughput, and fairness index. In this paper, two scenarios are used as follows:

2.2.1 Effect of changes in the number of users

This scenario is tested by simulating with a constant speed using random direction mobility type on 20 users, periodically changing the number of users namely 25 nUE, 50 nUE, and 100 nUE. Simulations are carried out using two packet scheduler comparisons Proportional Fair algorithm and the Max-Throughput algorithm in the Multicell case. Changes in the number of users are used based on the simulations conducted where the Quality of Service fluctuations occur up to the number of users 100. Moreover, each algorithm's graph generated by the packet scheduler tends to be stable[12].

2.2.2 Effect of user speed

This scenario was tested on 20 users moving at 3 km/h, 30 km/h, and 120 km/h. Simulations were carried out using two packet schedulers by comparing the Proportional Fair algorithm and the Max-Throughput algorithm in the Multicell case. The simulation is carried out for 100 seconds, where the user moves using the random direction mobility type, where the user handover is not defined so that the number of handovers that occur in the simulation is adjusted to the user's movement according to their respective speeds[13]. Services accessed by users, comparison of the number of services flows per user, and output information is the same as in scenario 1.

2.3 5G-air-simulator

5G-air-simulator is an Open-Source and Event-Driven that models critical elements of the 5G network interface. The simulator implements a network architecture with multiple cells, users, and mobility, with different application models such as Multiple Input, Multiple Output, and Multicast that can extend broadcast transmission schemes, predictor antennas, random access procedures, and NB-IoT[14].

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Table 1. Simulation parameters[6]

Parameters	Quantity
Bandwidth	10 MHz
Number of Users	25 nUE, 50 nUE, 100 nUE
Transport Layer	UDP
Scheduler Algorithm	Proportional Fair and Max-Throughput
Frstr	FDD
Speed	3 km/h, 30 km/h, 120 km/h
Vidrate	128
Simulation time	100 ms

Table 1 shows the simulator parameters that provide a set of newly designed components and 5G network interfaces technical management features. This simulation is done through a Virtual box that can virtualize and run or install a virtual Operating System[15]. By using Linux Ubuntu as an open-source operating system, the 5G-Air-Simulator can be performed[16]. With input parameters, the results will be in the form of various outputs. The output results will be stored in command-separated values (CSV), making it easier to find deals and analyze calculations.

2.4 Packet Scheduling Scheduling

A packet scheduler is an algorithm that allocates resource blocks to all UEs[17]. Packet scheduler aims to improve bandwidth efficiency and provide data services with network quality standards and maximum fairness by determining the data delivery process based on Proportional Fair and Max-Throughput scheduler algorithms with metric values[18].

a. Proportional Fair aims to increase the fair value allocated to the user. The metric value will be calculated based on the data rate value and the average throughput value obtained from the last metric calculation with the same flow[18]

$$m_{i,k}^{PF} = \frac{di\,k\ (t)}{\underline{R}\iota(t-1)}\ \ \underline{R}\iota\,(t) = 0.2\underline{R}\iota\,(t-1) + 0.8.\,r^{i}(t) \quad (1)$$

Where the notation in equation (1) is known as :
Where m is the metric value, i is the data packet flow (flow), k is the resource block, d is the data rate, r is the received data rate value, R is the received average throughput, and t is the metric calculation time. Packet scheduler Proportional Fair prioritizes sending data to the UE with the lowest average throughput value[8].

b. Max-Throughput aims to maximize throughput in the cell by allocating Resource Blocks to the user that can receive the highest throughput or UEs that have the highest data rate value, which is an estimate of the amount of throughput that can be obtained by users[19].

$$m_{i,k}^{MT} = d_{k}^{i}(t) \quad (2)$$

Where the notation in equation (2) is known as:
Where m is the metric value, i is the data packet flow (flow), k is the resource block, d is the data rate, and t is the measured calculation time. Packet scheduler Max-Throughput only serves UEs with the highest data rate values and can ignore UEs with relatively poor data rate values.

2.5 Quality of Service

Quality of Service is a technique for managing data traffic to reduce Packet Loss flow in the network[20]. The existence of Quality Service can help by ensuring users get better and guaranteed performance.

a. Delay is the time from sending packets from the sender until they are received at the destination, the average time of sending data packets from sender to receiver. The delay value starts to be calculated when the source sends when the destination receives the packet[8].

$$\text{Delay} = \frac{T_{rx} - T_{tx}}{\sum Rx} \quad (3)$$

Where the notation in equation (3) is known as:
T_{rx} = time of packet received at a destination
T_{tx} = Packet delivery time at the source
$\sum Rx$ = Received packets

b. Throughput is the speed (rate) of effective data transfer. The throughput value is obtained from the total number of data packets that arrive in a specific time interval and then divided by the duration of the time interval[21].

$$\text{Throughput} = \frac{\sum \text{RX Packet size}}{\text{Delivery Time}} \quad (4)$$

Where the notation in equation (4) is known as :

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$\sum Rx$ = Received packets

c. Fairness Index is the degree of fairness of the scheduling algorithm in the scheduled packet and the resource allocation to be sent. The maximum value of this metric is 1[10], Which indicates

$$\text{Fairness}_{\text{Index}} = \frac{(\sum_{i=0}^{n} x_i)^2}{n \sum_{i=0}^{n} x_1^2} \quad (5)$$

Where the notation in equation (5) is known as:
n = number of users
x = throughput of user

3. RESULT AND DISCUSSION

After collecting data using two scenarios using the 5G-air-simulator, the author obtained the results of throughput, delay, and fairness index, then analyzed the Quality of Service. The analysis is divided into 2 parts according to the predetermined scenario: the effect number of users with 25 nUE, 50 nUE, and 100 nUE. And the impact of speed with 3 km/h, 30 km/h, and 120 km/h, to find out which scheduling is better and more stable in 5G network services.

3.1 Testing Result

Test results will be obtained after integer input using values with packet scheduler Proportional Fair and Max-Throughput. Furthermore, using test tests on 2 scenarios, namely speed and user or UE changes. The results obtained are various outputs with high values. The output values are created in command-separated values (CSV), making it easier to search for in tracing and analyzing the calculations.

3.1.1 Effect of changes in the number of users

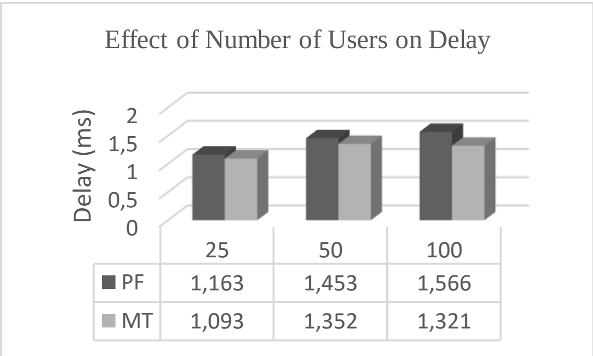

Figure 2. Effect of Number of Users on Delay

Figure 2 shows the simulation results when the delay affects the number of users. The lowest delay for Proportional Fair occurs at 25 UEs with 1.163 ms. For Max-Throughput, the lowest delay occurs at 25 UEs with 1.093 ms. At 50 UEs, Max-Throughput produces the highest delay with 1.352 ms; at 100 UEs, Proportional Fair has the highest delay with 1.566 ms. In conclusion, the delay for both schedulers increases because the number of UEs increases the waiting time for each user to be served longer. Max-Throughput has a better delay because, for small packets, users who queue do not take a long time, in contrast to Proportional Fair, which must consider cell quality.

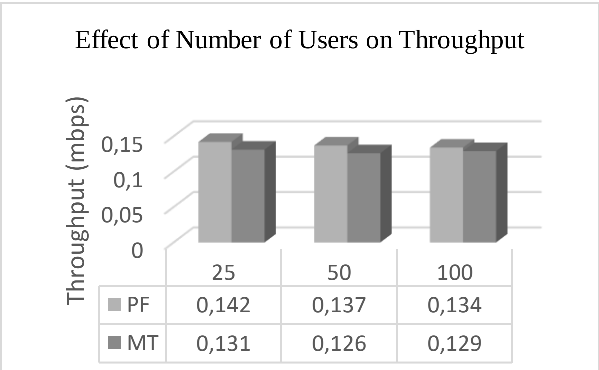

Figure 3. Effect of Number of Users on Throughput

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Figure 3 shows the simulation results when the number of users is affected by throughput. The results show Proportional Fair has a higher throughput than Max-Throughput. Proportional Fair gets a throughput of 0.142 Mbps. While Max-Throughput with a throughput of 0.131 Mbps. The lowest throughput in Max-Throughput occurs at 50 UEs of 0.126 Mbps, and Proportional Fair occurs at 100 UEs of 0.134 Mbps. The results show that the throughput decreases as the number of users increases because the bandwidth capacity will be divided among all users. Proportional Fair has higher throughput because this algorithm does not consider channel conditions and mainly balances throughput and fairness to users.

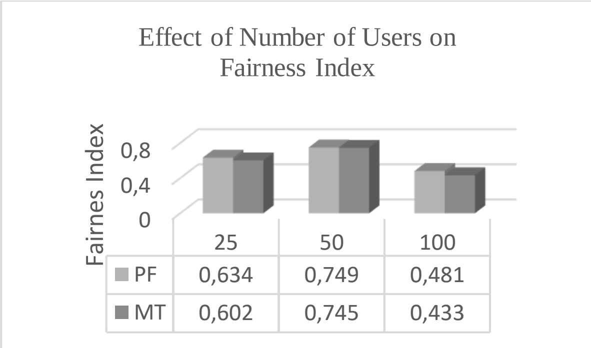

Figure 4. Effect of Number of Users on Fairness Index

Figure 4 shows the simulation results when the number of users is affected by the Fairness index. The fairness index value is obtained from the simulation of the effect of the number of users. The proportional Fair is 0.481. Compared to the Max-Throughput fairness index, which has a value of 0.433. Max-Throughput and Proportional Fair have fairness index values that decrease towards 100 UEs. It happens because as the number of users increases, more and more users are served, reducing the weight of fairness.

3.1.2 Effect of user speed

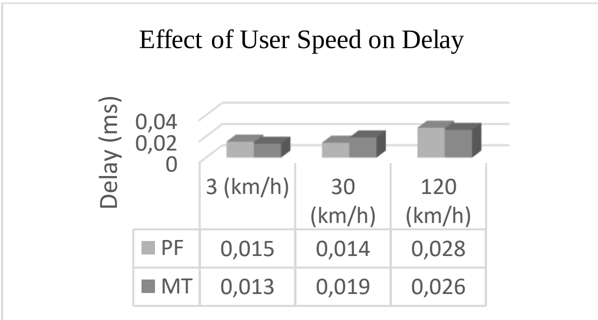

Figure 5. Effect of User Speed on Delay

Figure 5 shows that changes in user speed occur because the faster the user moves, the greater the delay experienced by the user. Overall, the Proportional Fair algorithm performs better when the user travels at a speed of 30 km/h with a delay value of 0.014 ms. In comparison, Max-Throughput gets a deal when the user travels at a rate of 3 km/h with a delay value of 0.013 ms.

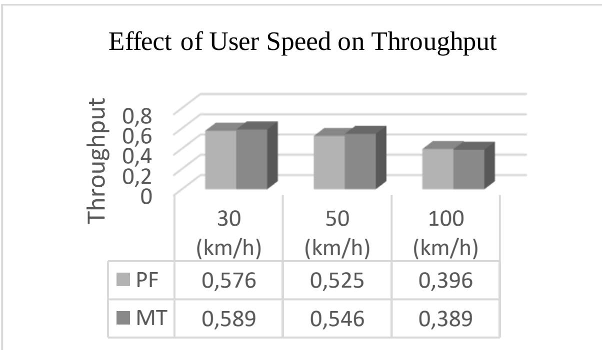

Figure 6. Effect of User Speed on Throughput

Figure 6 shows that the throughput value generated by the Max-Throughput algorithm provides a better deal than the. Proportional Fair algorithm at various user speeds. Max-Throughput gets the lowest value of 0.396 Mbps at 100 km/h. Proportional Fair had the lowest value of 0.396 Mbps at 100 km/h.

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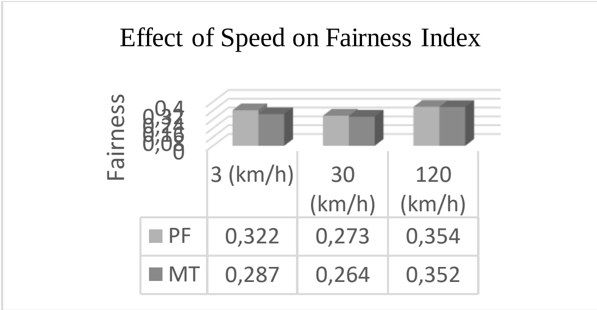

Figure 7. Effect of Speed on Fairness Index

Figure 7 shows that when users move at different speeds, it does not affect the real-time service caused by channel interference, not caused by increased traffic density as in the scenario of increasing the number of users. The highest Proportional Fair index value of 0.354 occurs when the user moves 120 km/h. While the highest Max-Throughput fairness index value of 0.352 occurs when the user moves 120 km/h.

4. CONCLUSION

In this paper, the research focuses on scheduling in 5G networks supported by testing 2 scenarios of changes in the number of users and changes in user speed. Based on the simulation results that have been carried out, increasing the number and rate of users will affect the Quality of Service on delay, throughput, and fairness index, where the greater the number of users that must be handled by the network, the Quality of Service will decrease. We can see this in the Proportional Fair simulation results, which get a throughput of 0.142 Mbps. While Max-Throughput with a throughput of 0.131 Mbps. The lowest throughput in Max-Throughput occurs at 50 UEs of 0.126 Mbps, and Proportional Fair occurs at 100 UEs of 0.134 Mbps. When the traffic load is small, the performance of the Proportional Fair algorithm is equivalent or even not much different from the Max-Throughput algorithm, whereas when the traffic load increases, the Max-Throughput algorithm performs better than the Proportional Fair algorithm. The more significantly the rate of user movement, the more the Quality Of Service decreases. For further research, it is expected that more packet scheduler algorithms can be implemented on 5G networks.

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