Journal of Theoretical and Applied Information Technology
31st July 2023. Vol.101. No 14

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

PERFORMANCE ANALYSIS OF RATE ADAPTATION ALGORITHMS BASED ON PARAMETERS MOBILITY MODELS AND PROPAGATION LOSS IN WIRELESS LANs

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ABSTRACT

Computer networks establish our day-to-day communications in this contemporary world. Wireless LANs (WLANs) have been beneficial for network connections within a small area referred to as a local area network. WLANs are elicited from the IEEE 802.11ac standard which is used in this paper. As WLANs are widely used for networking purposes the challenge is to maintain and improve the performance of Wireless LANs. Therefore, rate adaptation algorithms are applied to the system to enhance the working conditions of Wireless LANs. This paper primarily focuses on the performance of a few rate adaptation algorithms by changing different parameters like mobility models and propagation loss to note down the changes and efficiencies in various conditions based on metrics like average throughput and average delay so that their usage can be improvised in our daily lives.

Keywords: *IEEE 802.11ac, WirelessLANs, Rate Adaptation Algorithms, Mobility Models, Propagation Loss Model, Performance Analysis, Throughput, Delay*

1. INTRODUCTION

In computer networking, Wireless LANs play a pivotal role. As the name suggests the network connections are based on a high frequency of wireless links namely radio waves. Being wireless systems, the interconnections can be extended to certain areas of networks. Thus, these systems are broadly used in the workplace, residence, educational institutions, public areas, etc.

The performance of Wireless LANs should also be monitored and improved periodically as they are broadly used in our daily lives for communication and connections. The primary purpose of this project is to compare different rate adaptation algorithms in the IEEE 802.11ac standard Wireless LANs by changingparameters and evaluating the system's performance by metrics which has not been observed in previous works. This is a real challenge because many devices are connected to wireless systems to share, and transfer data and for many other applications. Hence, it is very crucial to improve the speed and reliability of the connections.

The network simulator ns-3 is used in this paper which is a distant event network simulator tool where it creates virtual nodes to examine real-world problems. Rate adaptation algorithms enhance the performance of Wireless LANs. In this paper, two rate adaptation designs are used namely Minstrel and Ideal. Both these methods are compared with a Constant Rate where no algorithm is used. Firstly, Minstrel is one of the rate control algorithms that solely select rates to provide proper estimations to the best accessible throughput. It is purely based on acknowledgment feedback where the success rate of future network simulations hinges upon the previous efficacies. An ideal algorithm is completely based on an explicit feedback system which means considering every possibility to improve the performance of the network. The ideal methodology is also known for its instantenous feedback and rate decision.

In this paper, maximum performance was shown by the Ideal algorithm. In ns-3, mobility models provide the movement of the nodes based on position, velocity, and acceleration [3]. Mobility models used in the proposed system are Random Walk2d, one type of Random Walk that is available and frequently used in transit. It is a mobility pattern lacking memory. The speed of the node currently possessed is not dependent on anycharacteristics that have been acquired previously. Secondly, it is one of the mobility models where the current position is fixed once it is set and remains fixed unless explicitly resetto a new value. Thirdly, In the Random Direction2d model, nodes typically choose a path at random and move in that direction until they hit the boundary or epoch [4]. The wireless signal strength at a group of receivers for any packet being delivered by a single transmitter is calculated using the propagation loss model. In the Log Distance path loss model, the path loss across the sender-to-receiver distance is exponential. It is suitable for suburban situations [5]. Quadratic route loss in free space is computed following Harald T. Friis' propagation model [6] referred to as Friis propagation loss.

2. LITERATURE SURVEY

In [1], Abdennour Zekri, and Weijia Jia worked on performance analysis of rate adaptation algorithms as there was relatively little research on IEEE 802.11p rate adaptation in automotive networks, thus the authors analyzed and assessed the existing 802.11 wireless network rate adaptation algorithms in a variety of vehicular settings to examine their performance.

In [2], SheelaC S, Joy Kuri, and Nadeem Akhtar proposed a system in order to conduct rate adaptation for IEEE WLAN802.11ax systems, this study examines the use of the Received Bit Information Rate mapping approach to abstract the physical layer.

Based on the previous observations it is understood that the need for rate adaptation algorithms is very pivotal in Networking. Therefore, It is equally necessary to study the behavior of rate adaptation algorithms under different scenarios to understand their efficiency to improve the performance of Wireless LANs.

3. PERFORMANCE METRICS

The performance of the methodologies methods above is evaluated based on the parameters given below.

3.1 Average Throughput

In Wireless LANs, the average throughput is defined as the total amount of data packetsthat are transmitted from the emitter(sender) to the receptor(receiver) per unit amount of time without any packet losses.

$$T_{avg} = \frac{\text{Total Number of data packets received}}{\text{amount of time}}$$

3.2 Average Delay

In computer networking, the average delay is defined as an outline and performance attribute where the average number of time frames spent by data packets in order to traverse them from an input channel to an output channel.

$$T_{delay} = \frac{(N_R - 1)}{N} \delta_{RoF} + \frac{N_L}{N} \delta$$

Tdelay is the average propagation delay for frames sent in the RoF and WLANs, where N is the number of local nodes, NL is the number of legacy APs and STAs, respectively[7].

4 RESULTS

4.1 Performance Analysis based on throughput

4.1.1 Average throughput is calculated by altering propagation loss to Log Distance

The graphs that are shown below illustrate the performance evaluation based on the throughput of Minstrel, and Ideal rate algorithms on three different Wi-Fi nodes namely 3, 10, and 18 by setting it to varied propagation loss model and mobility models as mentioned below.

Journal of Theoretical and Applied Information Technology
31[st] July 2023. Vol.101. No 14

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Table 1: Average Throughput for Mobility Model Direction2d

	Minstrel	Constant Rate	Ideal
3	26.2637	3.52148	41.416
10	23.7871	3.99954	39.9961
18	28.797	3.89487	40.7402

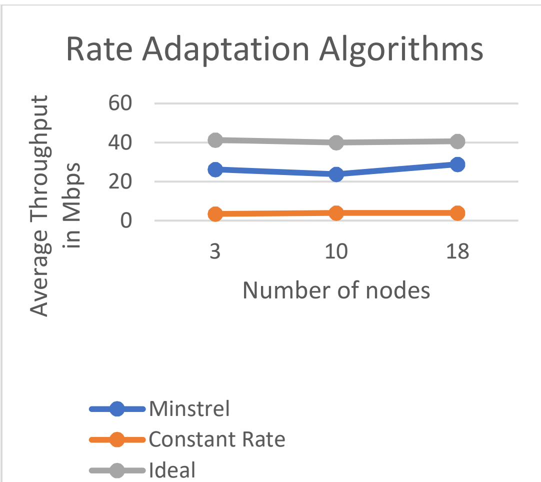

Figure 1: Average Throughput for Mobility Model Direction2d

The graph above illustrates the average throughput. Firstly, the propagation loss model is set to Log Distance, and the Mobility model is modified to Direction2d. Overall, the Ideal Rate Adaptation algorithm outperforms the Minstrel and Constant Rate algorithms with a maximum of 41.416 Mbps for 3 Wi-Fi nodes, and the least is observed when no algorithm is applied.

Table 2: Average Throughput For Mobility Model Constant Position

	Minstrel	Constant Rate	Ideal
3	36.9961	3.67773	41.5254
10	33.4023	4.04175	43.5605
18	24.5098	3.60547	41.625

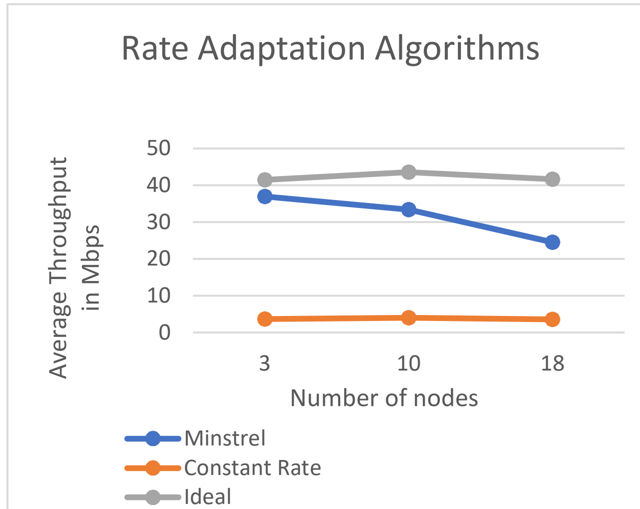

Figure 2: Average Throughput for MobilityModel Constant Position

The line graph above depicts the mean throughput for three different nodes. The mobility model is changed to a Constant Position. Overall, the Ideal rate adaptation algorithm efficiency is more than the othertwo algorithms as observed before with a maximum of 43.5605 Mbps for 10 Wi-fi nodes. Ideal and Constant Rate methodology followed a similar trend. But the pattern detected in Minstrel Algorithm is quite discrete.

Table 3: Average Throughput For Mobility Model Random Walk2d

	Minstrel	Constant Rate	Ideal
3	29.6816	3.58594	41.728
10	36.666	3.32864	43.8379
18	15.334	3.81734	40.1367

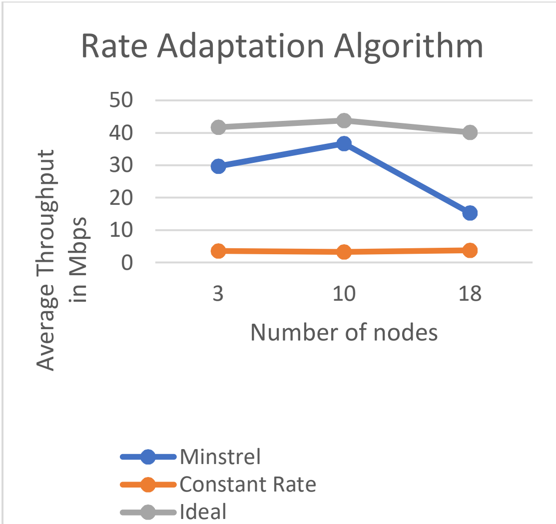

Figure 3: Average Throughput for Mobility Model Random Walk2d

The line graph above shows the average throughput for three different nodes. The mobility model is changed to a Random Walk2d. Overall, the Ideal Rate AdaptationAlgorithm efficiency is more than the other two algorithms as noticed in the previous two notations with a maximum of 43.8379 Mbps for 10 Wi-fi nodes.

4.1.2 Average throughput is calculated by changing Log Distance to Friis Propagation Loss

Table 4: Average Throughput for Mobility Model Direction2d

	Minstrel	Constant Rate	Ideal
3	41.5215	3.63086	34.6211
10	31.6035	4.04677	41.5573
18	16.5226	3.7094	44.3984

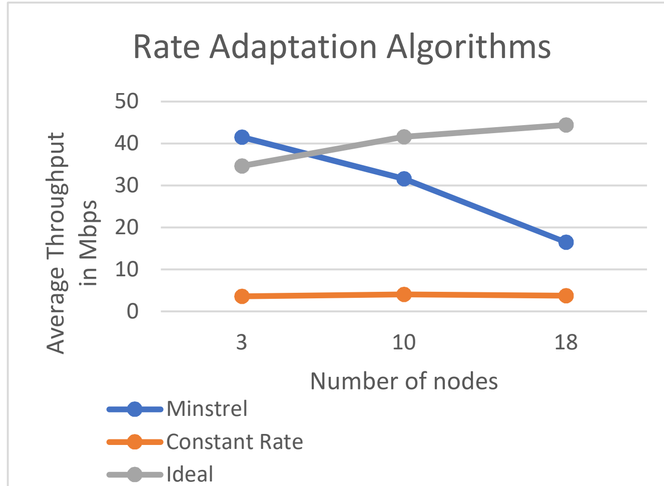

Figure 4: Average Throughput for Mobility Model Direction2d

The graph above depicts the average throughput for three different Wi-Fi nodes inWireless LANs. As mentioned previously,the propagation loss changed to Friis Propagation and Mobility Model is Direction2d. Overall, Ideal Rate Algorithm outperformed with a maximum of 44.3984 Mbps for 18 Wi-Fi nodes. All three categories of methodologies have shown different characteristics.

Table 5: Average Throughput for Mobility Model Constant Position

	Minstrel	Constant Rate	Ideal
3	41.3574	3.67969	41.6211
10	37.9062	4.04539	44.666
18	21.0332	3.50243	41.1172

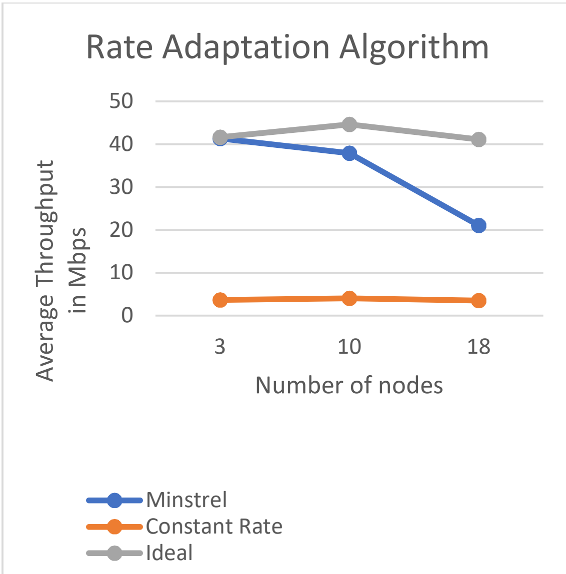

Figure 5: Average Throughput for Mobility Model Constant Position

The graph above illustrates the average throughput for three different Wi-Fi nodes inWireless LANs. The Mobility Model is altered to a Constant Position. Overall, the Ideal Rate Algorithm efficacy is more with a maximum of 44.666 Mbps for 10 Wi-Fi nodes. All three categories of methodologies have shown different characteristics.

Table 6: Average Throughput for Mobility Model Random Walk2d

	Minstrel	Constant Rate	Ideal
3	41.4629	3.55078	41.7949
10	22.4907	4.05255	42.9082
18	19.1254	3.63017	31.2741

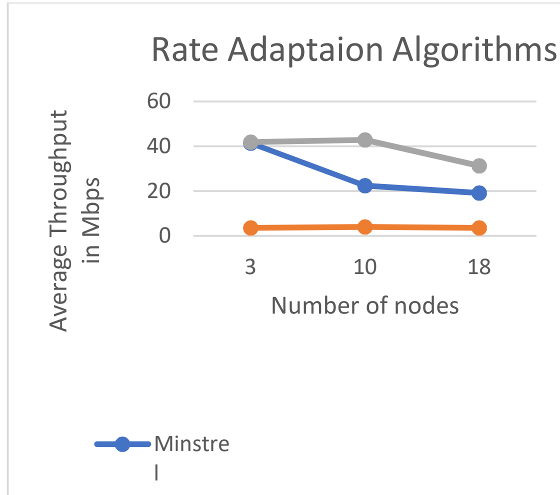

Figure 6: Average Throughput for Mobility Model Random Walk2d

The graph above shows the average throughput for three different Wi-Fi nodes in aWireless LANs. The Mobility Model is changed to Random Walk2d. Overall, the Ideal Rate Algorithm efficacy is more with a maximum of 42.9082 Mbps for 10 Wi-Fi nodes.

4.2 Performance Analysis based on delay

The tables that are shown below illustrate the performance evaluation based on the delay of rate algorithms on three different Wi-Fi nodes namely 3, 10, and 18.

4.2.1 Average Delay is calculated by altering propagation loss to Log Distance

Table 7: Average Delay for Mobility Model Direction2d

	Minstrel	ConstantRate	Ideal
3	41.3902	126.686	23.3217
10	52.5977	127.792	28.1988
18	42.2681	101.308	26.8359

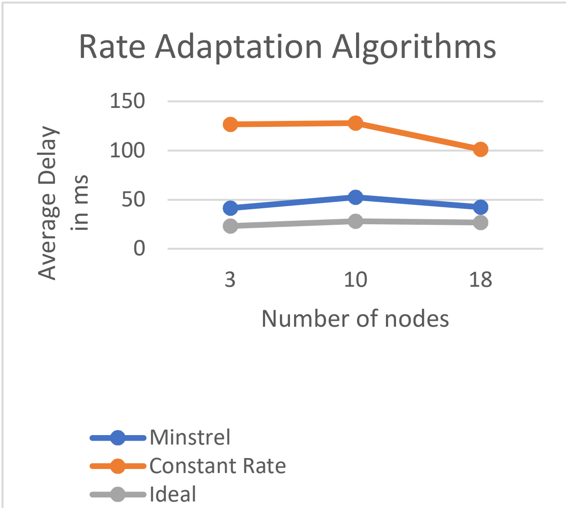

Figure 7: Average Delay for Mobility Model Direction2d

Adaptation algorithm with 3 Wi-Fi nodes which is about 23.3217ms, and the highest delay is recorded when no method is applied on the Wireless LANs area network (Constant Rate) with 10 nodes which is about 127.792ms

Table 8: Average Delay for Mobility Model Constant Position

	Minstrel	Constant Rate	Ideal
3	38.7156	100.953	22.532
10	53.7332	106.959	27.2184
18	50.3913	126.224	28.1801

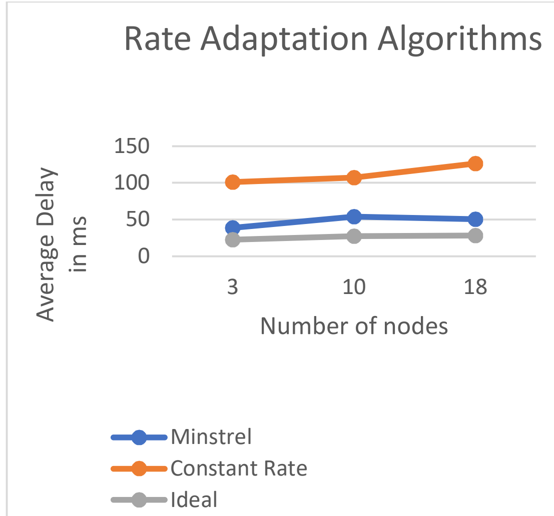

Figure 8: Average Delay for Mobility Model Constant Position

The table above illustrates the average delay for three different Wi-Fi nodes in Wireless LANs. The Mobility Model is altered to a Constant Position. Overall, the delay is less in the Ideal Rate Adaptation algorithm with3 Wi-Fi nodes which is about 22.532ms, and the highest delay is recorded when no method is applied on the Wireless LANs area network (Constant Rate) with 18 nodes which is about 126.224ms.

Table 9: Average Delay for Mobility Model Random Walk2d

	Minstrel	Constant Rate	Ideal
3	44.8731	112.438	21.8406
10	41.3864	140.138	26.4192
18	79.108	138.197	36.7365

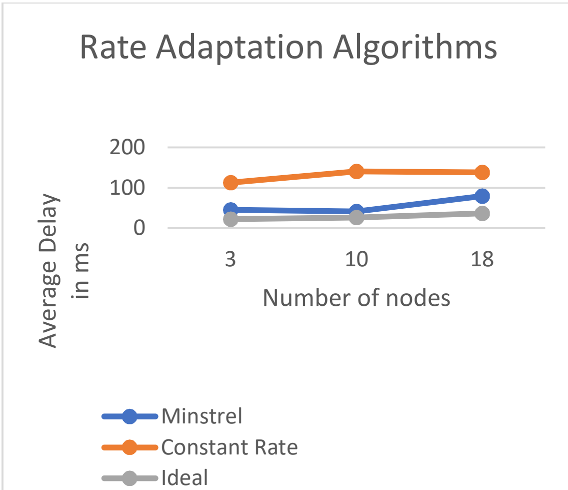

Figure 9: Average Delay for Mobility Model Random Walk2d

The table above illustrates the average delay for three different Wi-Fi nodes in Wireless LANs. The Mobility Model is altered to a Random Walk2d. Overall, the delay is less in the Ideal Rate Adaptation algorithm with 3 Wi-Fi nodes which is about 21.8406ms, and the highest delay is recorded when no method is applied on the Wireless LANs area network (Constant Rate) with 10 nodes which is 140.138ms.

4.2.2 Average Delay is calculated by altering Log Distance to Friis Propagation Loss.

Table 10: Average Delay for Mobility ModelDirection2d

	Minstrel	Constant Rate	Ideal
3	21.9931	105.589	18.5575
10	31.6035	120.438	25.5449
18	95.066	147.07	36.2698

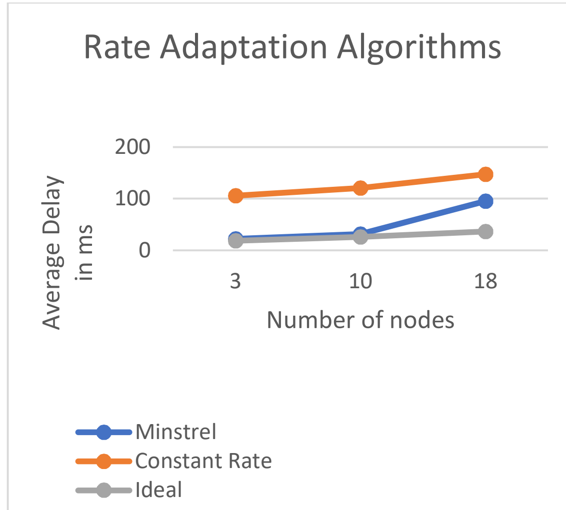

Figure 10: Average Delay for Mobility Model Direction2d

The table above depicts the average delay forthree nodes in Wireless LANs where the Mobility Model is altered to Direction2d. Overall, the delay is less in the Ideal Rate algorithm with 3 Wi-fi nodes which is 18.5575ms, and the highest delay is recorded when no method is applied on the Wireless LANs area network (Constant Rate) with 18 nodes which is 147.07 ms.

Table 11: Average Delay for Mobility Model Constant Position

	Minstrel	Constant Rate	Ideal
3	22.5569	103.394	21.1169
10	56.265	140.022	26.17777
18	116.446	152.757	81.1146

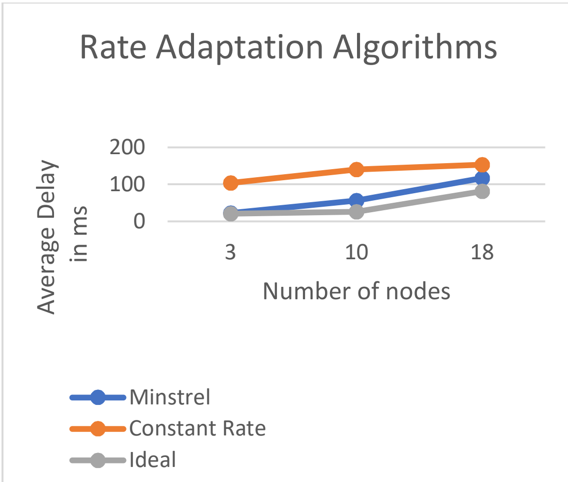

Figure 11: Average Delay for Mobility Model Constant Position

The table above illustrates the average delay for three different Wi-Fi nodes in WirelessLANs. The Mobility Model is altered to a Constant Position. Overall, the delay is less in the Ideal Rate Adaptation algorithm with 3 Wi-Fi nodes which is about 21.1169ms, and the highest delay is recorded when no method is applied on the Wireless LANs area network (Constant Rate) with 18 nodes which is about 152.757ms.

Table 12: Average Delay for Mobility Model Random Walk2d

	Minstrel	Constant Rate	Ideal
3	21.7688	144.409	19.216
10	94.0918	138.24	24.2314
18	87.8485	163.493	65.805

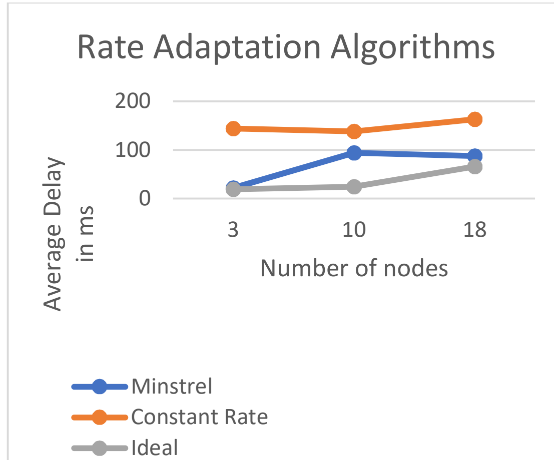

Figure 12: Average Delay for Mobility Model Random Walk2d

The table above illustrates the average delay for three different Wi-Fi nodes in WirelessLANs. The Mobility Model is altered to a Random Walk2d. Overall, the delay is less in the Ideal Rate Adaptation algorithm with 3 Wi-Fi nodes which are about 19.216 ms and the highest delay is recorded when no method is applied on the Wireless LANs area network (Constant Rate) with 18 nodes which are about 163.493 ms.

According to the literature survey and previous works related to rate adaptation algorithms experiments are conducted based on real-time applications like vehicular networks, bit data transmits, and different networking standards where in-depth analysis is been made. This paper visualizes the overall summary of the performance of rate adaptation algorithms under various circumstances without considering any application. Therefore, the conclusions which are drawn from this experiment might be different from the conclusions drawn from the previously conducted experiments. But the observations made in this paper are useful for future references like for a different network standard like IEEE 802.11 ax or for any other upgradation of a system or for any real-time application.

4. CONCLUSION AND FUTURESCOPE

Based on the observations of the research experiment. Firstly, it can be concluded that among all the parameters that are considered in this paper Ideal Rate Adaptation outperformed all the other algorithms. Secondly, the Friis Propagation Loss model has given maximum throughput and minimum delay for this experiment. Lastly, it can be inferred from the results that rate adaptation algorithms truly augment the efficacy of Wireless LANs compared to Constate Rate.

Below are the key important observations made from the research. The maximum throughput acquired is by the Ideal Rate Adaptation algorithm which is 44.67 Mbps with a delay of 26.18ms among all the different possible metrics where the number of Wi-Fi nodes is 10, Mobility Model is Constant Position and Propagation Loss is Friis. The minimum delay time is also observed in the Ideal Rate algorithm which is 18.5575 ms and throughput 34.6211Mbps among all the discrete possible parameters where the number of Wi-Fi nodes is 3, Mobility Model is Direction2d, and Friis Propagation Loss.

This experiment can be extended by implementing this solution in a real-time scenario like the vehicular network [1] to know its efficiency and compare the differences or similarities observed. The conclusions drawn from this paper can be used to upgrade the networking system's speed and reliability to enhance performance and to know how efficient the rate adaptation algorithms are in a particular scenario. The performance analysis made in this paper can also be expanded by considering other loss models, and mobility models in IEEE 802.11 ax environment.

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