

Packet Scheduling in wireless sensor networks for deadline constrained Data packets using Consensus Algorithm.

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Abstract

Wireless Sensor networks (WSNs) are basically designed for data aggregation, processing and transmitting considering many criteria satisfying many requirements such as minimal hardware availability, reduced energy consumption, dynamic traffic pattern at different links or channels, scalability and real time challenges as well. The advancement in real time applications of WSNs has led to the timely scheduling of data packets as and when they arrive. Real times internets packets are deadline constrained and are weighted to characterize relative importance with respect to other data packets. The work considers the problem of scheduling real time traffic in WSN. The proposed work finds an approach that maximizes weighted packet transmission before its deadline expires. The method also satisfies the quality of service for each link. The model considered comprises of interference constrained communication links which are ad-hoc in nature. The packet arrival process is a Bernoulli random variable which is independent from link to link.

Key Words: *Wireless Sensor Networks, Packet scheduling, Weights, Deficit, Deadline.*

1. INTRODUCTION

A huge collection of sensor nodes, communicating links, sinks and base station having a successful connectivity between themselves and also with the external devices is known as wireless sensor network as depicted in Figure -1. The WSN has enormous applications in the field of medical sciences, military, agriculture, unmanned vehicles, underwater monitoring and many more [Huang, 2023]. The communication and scheduling the traffic of packets among the sensor nodes along with the increase in the real-time applications in wireless networks, also becomes more tedious work [Aiqi Zhang, 2022]. Every packet in the traffic will have deadlines for transmission which is a very challenging problem due to stochastic nature of traffic arrivals and their

deadlines [Zaher , 2014]. Initially frame based framework was proposed by researchers to study real time traffic in wireless networks. Later it was assumed that packets can arrive at any time-slot during a frame and the deadline of a packet can also be at any time after the arrival. Packet scheduling algorithms can efficiently enhance packet delivery through WSN. Packet scheduling is defined as the process of selecting or rejecting a data packet for transmission based on some decision [Xing, 2023]. Based on various algorithms the data packet will be transmitted in the network and there is a probability of dropping the packets also in accordance with its large size, packet arrival rate, bandwidth and deadline of packet. The proposed work assumes that the arrival and deadline information is available at the beginning of the frame, therefore prediction becomes easy. In this paper, firstly Earliest Deadline First (EDF) algorithm is considered, where the algorithm prioritizes links having least remaining time packets. If two links have packets with the same least remaining time, then tie is broken giving priority to higher weight links.

Secondly the performance of a low –complexity greedy policy called the largest deficit-first (LDF) policy is evaluated. The algorithm schedules packets from the link that has highest deficit. Any possible tie is broken according to class weights. Further, Continuous Minloss Throughput Optimal (CMTO) is considered which looks at the existing packets waiting in the queue. It then finds the schedule that minimizes the loss over the queued packets. Lastly, Competitive Ratio Algorithm is an improvement over the previous ones. It achieves 75% of the optimal weighted packet transmission.

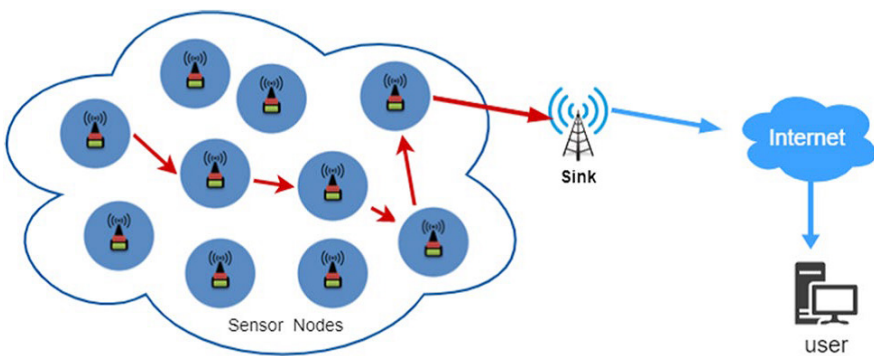


Figure - 1 Typical Wireless sensor network structure. [Zaher , 2018]

The remainder of the paper is organized as follows. Section 2 presents a literature study of many existing packet scheduling algorithms of WSNs. In section 3, the proposed algorithm is given. Section 4 analyzes the performance of the proposed scheduling algorithm in terms of QoS, Deficit and other parameters. In Section 5, finally, conclusions and future work are presented.

2. LITERATURE REVIEW

B. Huang et., al proposed two packet scheduling algorithms for rechargeable sensor networks on the basis of signal to interference and noise ratio model. Priority based framework for scheduling and algorithm for energy efficient batteries are discussed based on the priorities by scheduling short transmission distance of packets first. The simulation results say that battery capacity has less effect on the packet scheduling delay.

The authors of paper [Chen, 2022] proposed a priority dynamic adjustment packet scheduling (PAS) algorithm reducing the queuing delay of packets in a node resulting in improvement in quality of services and reducing end to end delay by 30% compared to existing algorithms

In [Jandaeng, 2011], authors have concentrated in reducing packet collision by introducing algorithms that can influence on delay of data transmission in real time WSNs. The algorithm reduces packet congestion in MAC layer. The results are better compared to simple CSMA/CA and other approaches in terms of throughput average and channel utilization but delay is higher.

Ali Almazroi et.al, [Almazroi, 2021] presents priority packet scheduling for data delivery in multipath routing for urgent traffic to sink node with a suitable delay by decreasing end to end delay. This paper presents the packet priority scheduling multipath routing (PPSMR) using remaining energy, available buffer size, and packet reception ratio, number of hops and delay to select the best next hop. Results show that PPSMR has lower average delay with low energy consumption and high packet delivery ratio than the existing.

The authors in [Gomathi, 2015] developed packet scheduling algorithms in WSN to increase delivery of packets such as Nearest Job next-with combination (NJNC) which outperforms in mobility assisted data collection. The simulation result shows that the proposed algorithm has better results than Nearest Job Next (NJJN).

The authors in [Sharma, 2020] present algorithm to schedule the activities of sensor nodes to form scheduling rounds autonomously to have at least one communication path from sensor nodes to base station. A reinforcement learning technique named Nash Q-Learning based node scheduled algorithm is proposed where each node autonomously learns its optimal action to maximize

coverage and connectivity. The algorithm proves to be more accurate in terms of accuracy and reliability in comparison with existing algorithms.

H. Zhang et. al, in [Zhang, 2024] present sensor node scheduling strategy by employing Dueling Double Deep Q-Network (D3QN) algorithm which optimizes estimation efficiency as depicted in results showcasing the improvements in estimating accuracy and network efficiency. A multilevel trust base optimal stochastic data scheduling model is proposed in [Komuraiah, 2024] which is classified in to multilevel trust model and optimal stochastic data scheduling. The outputs when compared with earlier approaches show better results in terms of energy efficiency and delivery ratio.

The authors in [Yang, 2021] developed a decentralized scheduling function which considers the probability and distance of cell rather than simple random selection. The results show lower end-to-end latency and also no extra costs. The paper [Soundararajan, 2023] proposes Enhanced Scheduling algorithm (ESA) with probabilistic approach called Random Classical Game theory to reduce delay in WSN. It is demonstrated in the results that energy consumption is reduced and throughput is increased.

Smriti Sachan et. al, presented [Smriti Sachan, 2020] a work in probabilistic algorithm to analyze the network connectivity within the network in WSN. The method results in increased network connectivity, communication sustainability and reduced energy consumption. The authors in [Shenghe, 2018], proposed deep neural networks to optimize link scheduling and power control. The simulation results show that the proposed method exhibits five orders of magnitude speedup with less than nine percent performance loss, making real time usage practical.

In [Shuran Sheng, 2021] authors have introduced a multiple tasks scheduling problem along with deep reinforcement learning (DRL) to solve both time scheduling and resource allocation. The algorithm outperforms the existing methods in literature in terms of average task satisfaction degree and success ratio.

The contributions of the paper are:

1. It is shown that by allocating nonnegative weight to each link, reduces packet loss due to random scheduling.
2. A heuristic consensus algorithm that intelligently assigns the weights to calculate a good lower bound based on the network topology.
3. The evaluation of performance of LDF policy and the proposed consensus algorithm via simulations.

3. PROPOSED MODEL

The paper considers wireless network consisting K number of links. Its set is called k .

The time period is divided as slots and one packet can be transmitted successfully in one time slot if none of the other packets are being transmitted. A general interference model is considered

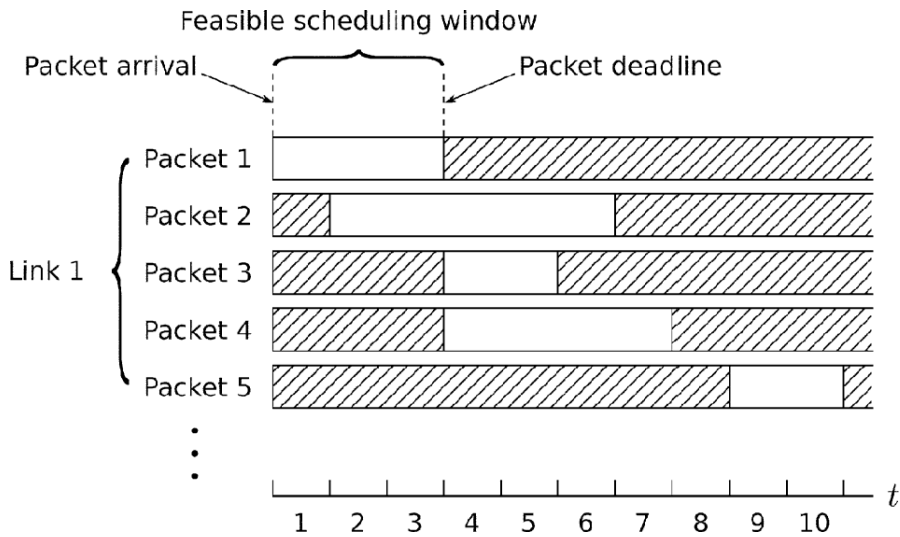


Figure- 2 Example of Packet Arrival [Xiaohan, 2014]

The proposed model has interference constrained communication links which are collocated or ad-hoc. Packet arrival process is a Bernoulli random variable different from link to link as depicted in Figure-2. Earliest Deadline First (EDF) is an algorithm which prioritizes links having least due time packets. When two links have equal due time, then tie breaking will be performed giving priority to higher weight links. Largest Deficit First is the algorithm that schedules packets with highest deficit in a particular link. If there is a tie then weights is considered to break the tie.

Continuous Minloss Throughput optimal algorithm checks the waiting packets in the queue. Later, a new schedule is developed that minimizes the loss over the queued packets. The inputs considered are packet arrival probability (λ), deadline (τ) and weight (w). The simulation results show the fraction of (weighted) packets transmitted, number of packets transmitted and evolved deficit. A graph of fraction as a function of links is generated. Also, deficit as a function of time is plotted.

4. RESULTS AND DISCUSSION

The code is developed in MATLAB. The simulation requires certain inputs such as packet arrival probability (λ), deadline (τ), and class weight (w). Given the input, the code prints fraction of (weighted) packets transmitted, number of packets transmitted and evolved deficit. It also plots the fraction as a function of links. Another interesting plot shows the evolution of deficit as a function of time.

Link 0						
Link 1						
Link 2						
Link 3						
Link 4						
Link 5						
Time Slots	1	2	3	4	5	6
Schedules	M2	M4	M3	M2	M4	M3

Figure- 3 Example of different links, schedule and packet arrival

Initially, given some arrival rates, the algorithm calculates the probability with which the packets arrive to the links as shown in Figure-3.

Table- 1 Number of packet arrival

Number of Packets	Probability	Actual
0	0.3487	0.3491
1.0000	0.3874	0.3863
2.0000	0.1937	0.1937
3.0000	0.0574	0.0579
4.0000	0.0112	0.0114
5.0000	0.0015	0.0014
6.0000	0.0001	0.0002
7.0000	0.0000	0
8.0000	0.0000	0
9.0000	0.0000	0
10.0000	0.0000	0

Given some arrival rates, it calculates the probability with which $\leq L$ packets arrive to the links

i) Earliest Deadline First (EDF) implementation

The EDF algorithm schedules tasks based on their deadlines, with the task having the earliest deadline being given the highest priority. It calculates the deficit for each link and updates it based on the scheduled packets.

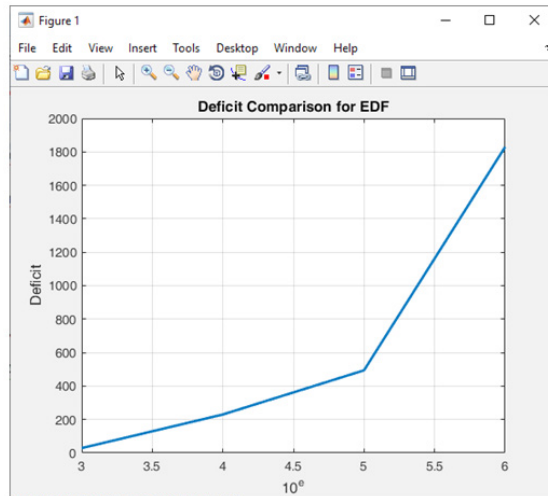
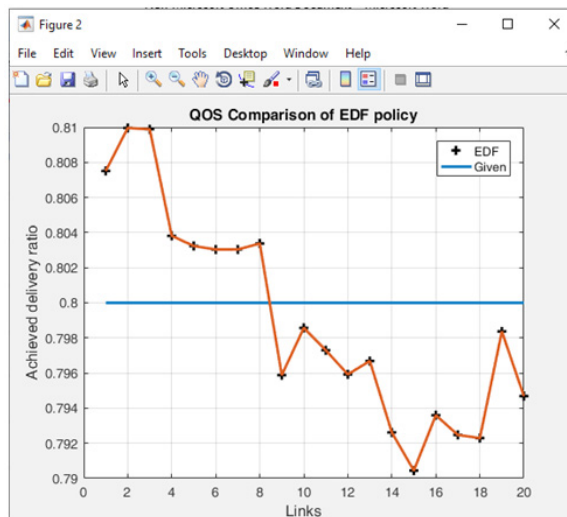


Figure - 4 a) Deficit comparison for EDF



b) QoS comparison of EDF policy

The algorithm implements the Earliest Deadline First (EDF) scheduling algorithm with arbitrary tie-breaking and generates graphs to visualize the deficit and Quality of Service (QoS) over time. Different values for time slots are considered with powers of 10. The data packet arrival events are generated randomly based on the arrival rate λ . A stack of Deadlines is initialized. For each time slot t , deadlines are updated and determine which packets to schedule based on the earliest deadline. The graphs generated visualize the deficit with respect to different timeslots in Figure- 4.a. Also, Quality of Service comparison of EDF policy with respect to links is shown in Figure- 4.b.

ii) LDF_First_EDF

Table - 2 Start and End Time intervals OF packets.

	Appropriateness of the data	Total packet arrived	Total packet scheduled	Delivery ratio-aggregate	Difference of arrival and schedule	Cumulative deficit at the end	Cumulative drop at the end
START	1.0200	1020	886	0.8686	134	6	133
END	1.0200	1020	841	0.8245	179	15	179
START	0.9987	9987	8696	0.8707	1291	7	1290
END	0.9987	9987	8250	0.8261	1737	19	1737
START	0.9867	98671	86634	0.8780	12037	18	12037
END	0.9867	98671	82190	0.8330	16481	11	16481
START	0.9891	989091	865344	0.8749	123747	8	123747
END		989091	821805	0.8309	167286	5	167286

Table-2 shows the total packets arrived, scheduled, aggregate of delivery ratio, Difference of arrival and scheduling, cumulative deficit at the end and cumulative packet drop at the end.

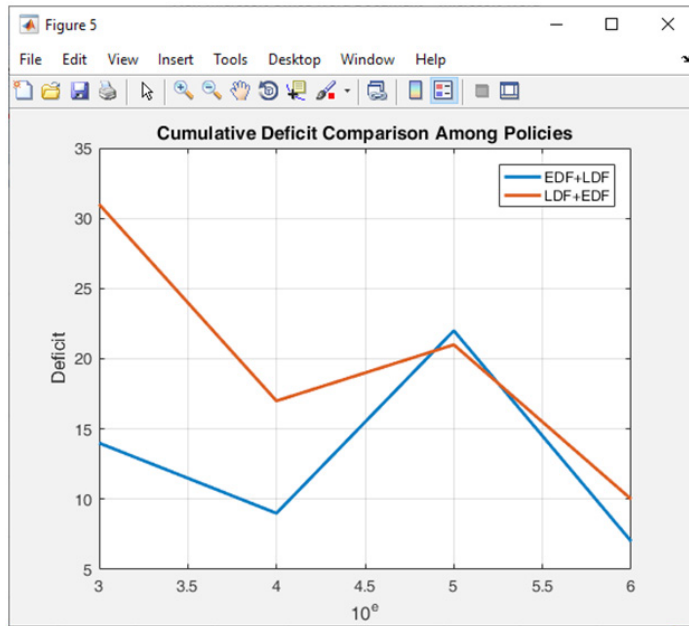
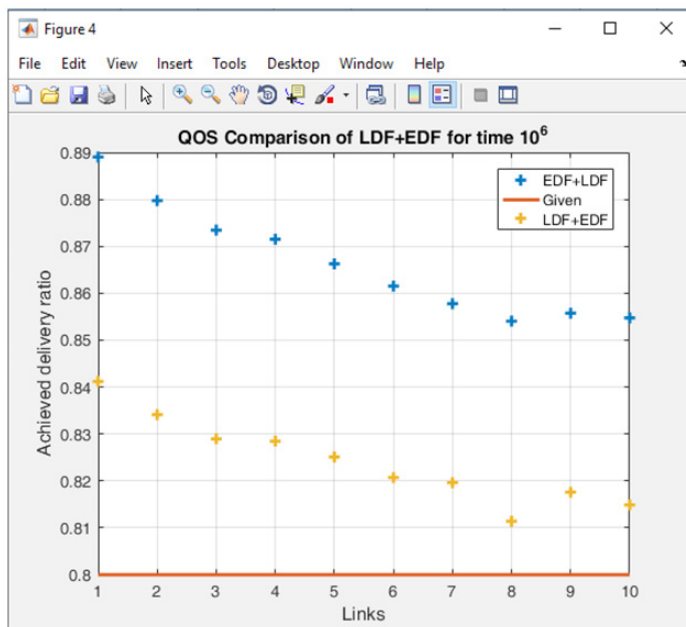


Figure - 5 a) Cumulative Deficit comparison among policies



b) QoS comparison of LDF + EDF for time 10^6

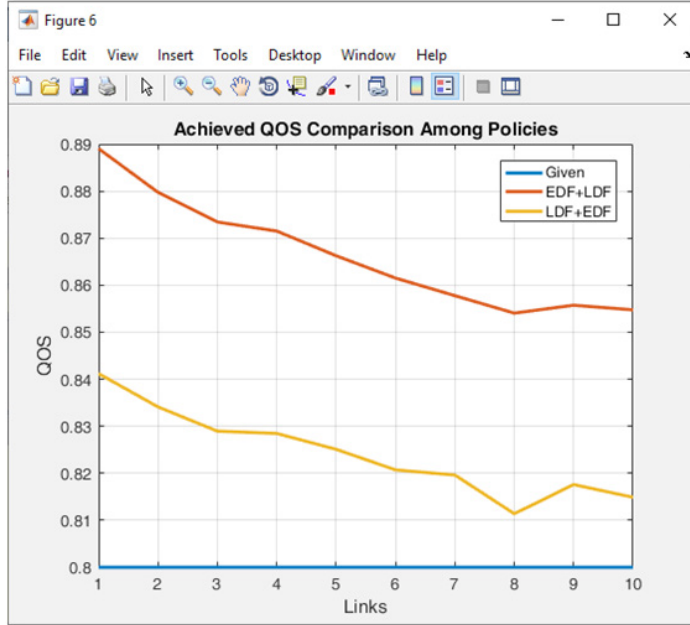


Figure - 6 Achieved QoS Comparison Among Policies

Figure 5 and 6 depicts the comparison between policies in terms of QoS for time 10^6 . Also drop calculation is performed.

iii) Reduced cost Approach and Cost Minimization approach

This approach compares the Cost Minimization (CM) policy with the Reduced Cost approach.

The algorithm is as follows:

1. Initialization of Lambda value, $L=10$;
Lambda=ones (1,L)*0.9;
2. Weights are initialized using an exponential decay function: $w=0.8^{(1:1:L)}$;
3. Time slot: $T=10^5$;
4. Tao_max=1;
5. A number of iterations are done and the CM policy is implemented within nested loops:
for tao1=tao_max;, tao=tao1*ones(1,L);
6. Sm=zeros(L,T);

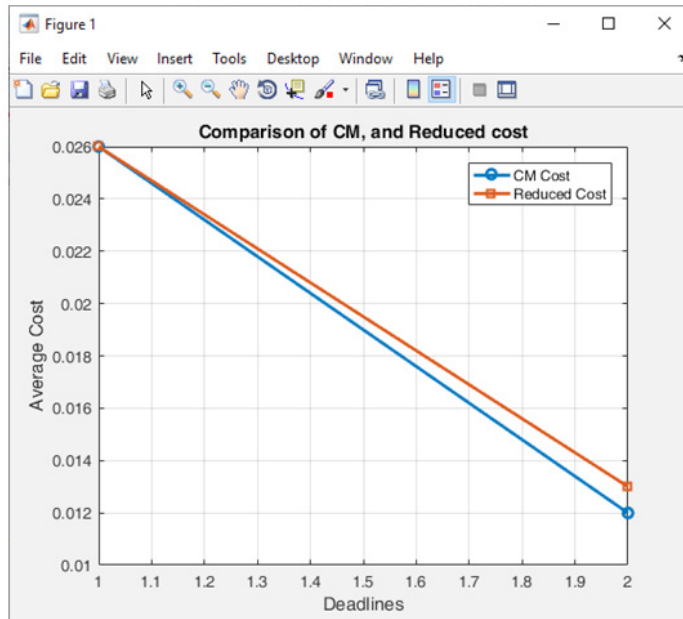


Figure- 7 Comparison between CM, and Reduced Cost

The Cost Minimization (CM) policy schedules packets based on their weights and deadlines. Various lambda values and weights are initialized to simulate different scenarios. Calculation of deficit for each link and updating is done. Comparison of performance of CM policy with the Reduced Cost approach is shown in Figure-7. Reduced cost is a policy when all the deadlines are one. In the reduced case, scheduling the highest weight link with existing packet is the optimal policy Comparison between CM, and Reduced Cost

iii . SP_EDF_WDF_comparison

The Comparison of Multicast Earliest Deadline First (EDF) algorithm with class weight based tie breaking and Static Priority (SP) policy. It schedules a link with packet in descending order of factor equal to $\tau \cdot \lambda$. The simulation generates graphs for weighted loss vs. time and Quality of Service (QoS) over (10^6) time slots.

The parameters considered are listed out in Table -3.

Table -3: Parameters for algorithm comparison

Sl.No	Parameters	Values
1	Lambda-Arrival rates for each link	0.26, 0.19, 0.15, 0.14, 0.09,0.07, 0.04, 0.02, 0.02, 0.01
2	L-Number of links	Length of lambda
3	Tao-Deadlines for each link, set of 2 for all links	2*ones(1,L)
4	Tem_weight-Random weights for each link	Rand(1,L)
5	W-Normalized weights sort(temp_weight)/sum(temp_weight)	round(w,4)
6	Factor-Product of weights and arrival rates	100*w.*lambda round(factor,4)
7	Static _Priority-Based on sorted factors	1:10

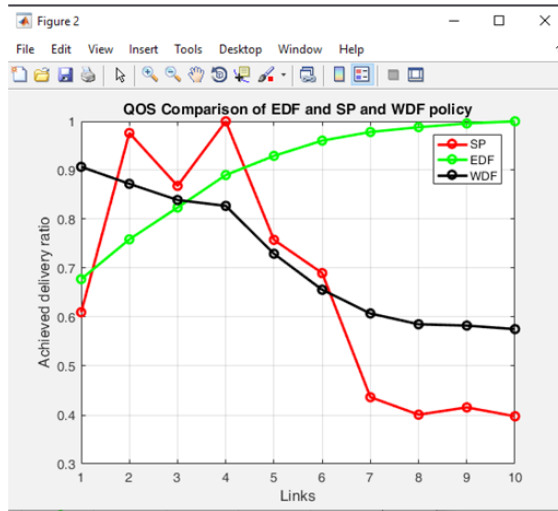


Figure - 8 QoS comparison of EDF and SP and WDF policy

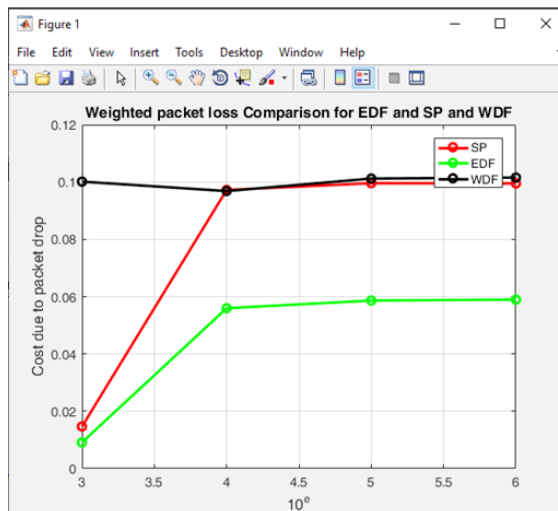


Figure - 9 Weighted packet loss comparison for EDF and SP and WDF

Figures 8 and 9 depicts the QoS comparison of EDF, SP and WDF policies in terms of packet scheduling and loss. Multiclass EDF algorithm, it does EDF with class weight based tie breaking

Static priority, it schedules a link with packet in descending order of factor= $\tau \cdot \lambda$.

Generates weighted loss vs. Time graph for both the policies. QoS graph is plotted at 10^6 times slots.

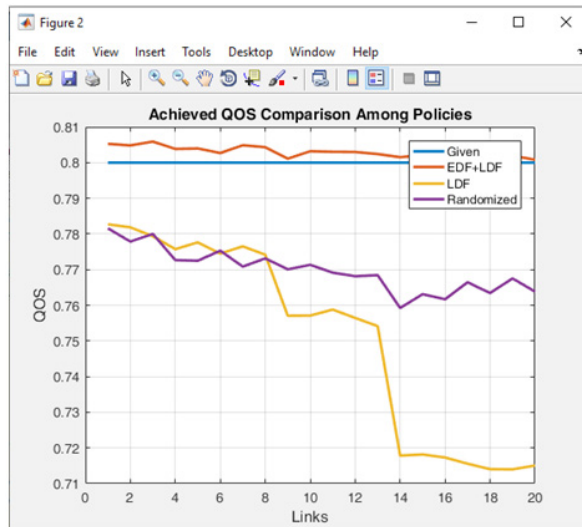


Figure - 10 Achieved QoS comparison Among Policies

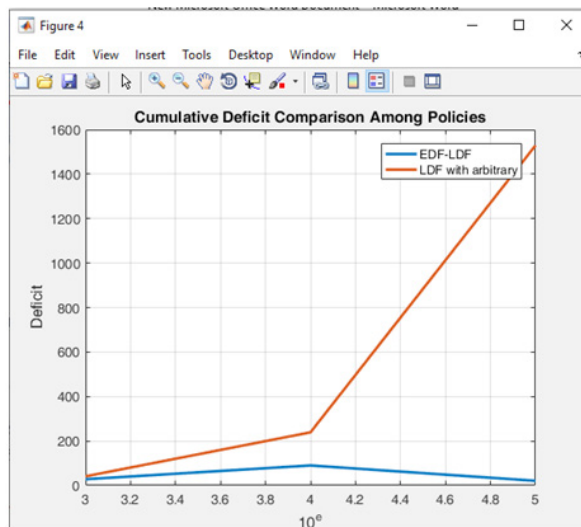


Figure - 11 Cumulative Deficit Comparison among Policies

EDF+LDF QoS is better when compared to LDF and Random scheduling as shown in Figure-10 and Cumulative deficit is also moderate in EDF+LDF depicted in Figure-11

5. Conclusion

The paper considered the problem of scheduling real-time traffic in wireless networks under random arrivals and shorter deadlines along with general interference model. Deficits and QoS are employed to value the stability performance of scheduling policies such as EDF, LDF, EDF +LDF and SP. The parameters considered for algorithm comparison are arrival rates, number of links, deadlines and factor. It is proved that the efficiency of EDF+LDF is better than other policies. Further, the weights are considered to schedule by applying priority concept. The framework is suitable for general instances, for both deterministic and randomized algorithms in both normal and adaptive adversary environments.

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