IWO Based Adaptive Algorithm for Packet Scheduling Problem

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Abstract— **This paper deals with the packet scheduling problem in a computer network. Multimedia services, such as Voice-over-IP (VoIP) and Video-on-Demand (VoD), rely on IP networks thus may suffer from unwanted delays, high packet loss rate and large jitter because of intense traffic load on the network. Traffic needs to be prioritized in order to meet the Quality-of-Service (QoS) requirements and ensure reliable media transmission. This paper presents an idea of modifying Weighted Round Robin (WRR) scheduling algorithm to adapt to the incoming traffic by applying Invasive Weed Optimization (IWO) metaheuristic search algorithm for finding the best set of the weights with every time step. Simulation study of the performance of the proposed scheduling algorithm, called Adaptive Weighted Round Robin (AWRR), shows that it can deliver better results than basic scheduling algorithms.**

Keywords — packet scheduling; metaheuristic; QoS; IWO; algorithm; experimentation system

I. INTRODUCTION

Time sensitive multimedia services, such as VoIP and VoD, play an important role in modern IP networks. Due to many factors, media packets transported on a packet-switched network may suffer from long delay time, large jitter and high packet loss rate. These problems may have destructive influence on quality of time-sensitive media streams. The traffic needs to be prioritized in order to meet the QoS requirements, i.e., to achieve low delays and jitter of media packets to allow media streaming or VoIP telephony.

This paper deals with packet scheduling problem in a computer network. The main idea for the algorithm proposed in this paper is to modify known WRR scheduling algorithm to make it adapt to the incoming traffic and, hopefully, achieve better results. The WRR generates scheduling sequence according to the weights of packets. The modification consists in (i) making the weights adjustable with every time step and (ii) applying the IWO metaheuristic algorithm for finding the best set of weights in adaptive manners.

Moreover, the paper presents the comparative analysis of efficiency between basic queuing algorithms and the created complex metaheuristic algorithm for solving packet scheduling problem.

The rest of the paper is organized as follows. In Section II, the related works are discussed. Section III describes briefly the formulation of the considered problem. The considered three algorithms for solving the problem, including the created algorithm, are presented in Section IV. The designed and implemented experimentation system is shortly presented in Section V. Section VI is devoted to investigation containing experiment set-up, as well as the presentation and discussion of the obtained results. The final remarks with a conclusion appear in Section VII.

II. RELATED WORK

There are available papers concerning packet scheduling mechanisms for QoS requirements.

In [1], the problem of two-stage packet scheduling on parallel processors is considered. This paper is the main reference for this work as it assumes applying meta-heuristics for packet scheduling problem. It is assumed, that each processor schedules packets according to WRR rule. In order to deliver required level of the QoS parameters of WRR, the two stage approach is used such that QoS requirements are met for all distinguished traffic classes. Adaptation of WRR weights relies on the adaptation through identification methodology with the Diagonal Recurrent Neural Network (DRNN) applied as the model of QoS parameters.

Paper [2] describes interesting concepts of QoS packet scheduling approaches. Author proposes a charge-based optimization model for packet scheduling aiming to maximize overall satisfaction, as well as to develop a simple and effective scheduling policy for the environments where packets have predefined hop-by-hop time schedules.

Paper [3] applies the proportional model in the differentiation of queueing delays, and investigates appropriate packet scheduling mechanisms.

In [4], an approach to adaptive packet scheduling is presented, based on adaptation through identification methodology. Identification refers here to prediction of future QoS parameters of processed traffic, basing on values of parameters of primary scheduling algorithm.

The authors of [5] present another scheduling discipline, called Nested Deficit Round Robin (NDRR). It splits each DRR round into one or more smaller rounds, within each of which we run a modified version of DRR.

In the last years many metaheuristic algorithms based on the imitation of processes in nature, in particular concerning ants, swarms and invasive weeds, were created for solving optimization problems in various areas, e.g., in ecology [6], and in managing computer systems [7].

The implementation of nature based algorithms can give some profit. In this paper, the concept of adaptive packet scheduling using the two stage approach [1] [2] [4] with the IWO metaheuristic [6] [7], is used in order to propose more efficient way of packet scheduling in computer network.

III. PROBLEM STATEMENT

For the purpose of this paper, it is assumed, that the network traffic is generated on a single link between two side routers denoted in Fig. 1 as node A and node B.

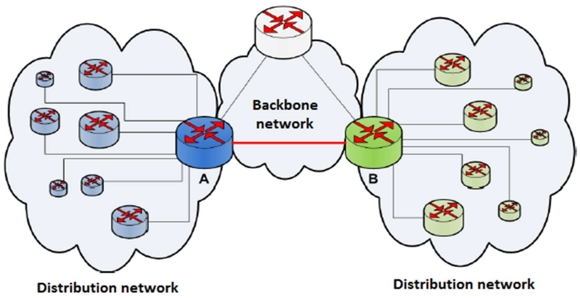

Figure 1. The considered fragment of the network.

An aggregated stream of packets incoming into the network node is composed of three types of packets characterized by the same source and destination addresses. The distinguished types of packets are: video, audio, and www packets.

The general scheduling problem is to find in each time step $A(n) = [video(n); audio(n), www(n)]$ such that $A(n) = \arg\min D(n)$. The criterion function D is a defined composition of three elements:

$$D[video(n)] = w_{video}(n) * (time_{out} - time_{in}),$$

$$D[audio(n)] = w_{audio}(n) * (time_{out} - time_{in}),$$

$$D[www(n)] = w_{www}(n) * (time_{out} - time_{in}),$$

where $w\ (n)$ are weights (changed in each time step), $time_{out}$ is the time moment when packet is processed through network, $time_{in}$ is the time moment when packet arrives to management system.

Following the two stage approach (described in detail in [1]), the problem to be solved in this paper consists in finding such a vector of local scheduling algorithm's weights: $w^{*}(n) = [w_{video}(n),\ w_{audio}(n),\ w_{www}(n)]$ for which the traffic delay is minimized in the sense of a given criterion.

In this paper, we concentrate on the minimum average delay denoted by Q.

IV. ALGORITHMS

A. *Reference Algorithms*

As the reference algorithms, two well-known scheduling algorithms are taken into consideration: Priority Queuing algorithm, here denoted as PQ, and Weighted Round Robin algorithm, denoted as WRR. PQ schedules traffic such that the higher priority packets get served first. Three different priorities are considered - *High*, *Medium*, and *Low*. The lower priority packets only get serviced if there are no higher priority packets waiting. WRR algorithm generates scheduling sequence according to the weights of packets. For more detail concerning these algorithms see [1].

B. *AWRR algorithm*

This algorithm is an own modification of WRR algorithm. The main idea is to automatically adjust weights with every time step. IWO metaheuristic algorithm is used for finding the best set of weights.

The algorithm requires performing the following steps:

Step 1. Generating an initial population (a random set of weights).

Step 2. Calculating fitness based on the criterion function (e.g., Q = minimum average delay) and checking the constraints (a packet loss rate).

Step 3. Making reproduction (based on plant fitness).

Step 4. Choosing new seeds near to the parent plant (randomly distributed with zero mean and specified standard deviation).

Step 5. Producing seeds by each weed when the maximum number of weeds in a colony is reached.

Step 6. Weeds with lower fitness are eliminated to reach the maximum allowable population in a colony.

The process continues until stop condition is satisfied (e.g., maximum iteration is reached).

V. EXPERIMENTATION SYSTEM

The designed experimentation system has been implemented in MATLAB environment.

The system gives opportunities for:

- Packet scheduling on a single link between two side routers,
- Using the type of traffic such as video, audio and www packets,
- Performing the following algorithms: PQ, WRR, and AWRR - IWO based Adaptive Weighted Round Robin algorithm.

The system consists of the following modules:

- Packet generation module,
- Simulation module,
- PQ algorithm module,
- WRR algorithm module,
- AWRR algorithm module.

The experimentation system can be treated as input-output system (see Fig. 2).

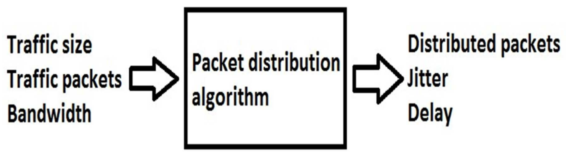

Figure 2. The concept of the experimentation system.

The user can carry out the simulation experiments taking into consideration the following variables:

Input parameters: sort of traffic, proportion of traffic, traffic load, bandwidth, simulation time.

Output parameters: the average packet delay, maximum packet delay, packet jitter.

VI. INVESTIGATION

A. Experiment Setup

The following setup was used in order to achieve similar queuing properties. The goal was to set the same priorities (weights) in AWRR and WRR algorithms such that the comparison is accurate.

Inputs:

- Minimum combined (weighted) average delay as a criterion for AWRR algorithm:

$$Q = min\begin{pmatrix}1.5 * avgvideodelay + 1.2 * avgaudiodelay \\ +0.1 * avgwwwdelay\end{pmatrix}.$$

- Weights for WRR algorithm: $w_{video} = 15, \;\; w_{audio} = 12, \;\; w_{www} = 1$ (similarly to AWRR);
- Priorities for PQ: video packets: *high*, audio packets: *medium*, www packets: *low*;
- Simulation time: 100 [µs];
- Traffic load: 120% of bandwidth ;
- Type of traffic: 40% video, 40% audio, 20% www packets.

Outputs:

- Packet delay,
- Packet jitter .

B. Results and Comments

The results of experiment are shown in a form of plots for all three algorithms: PQ, WRR, and AWRR.

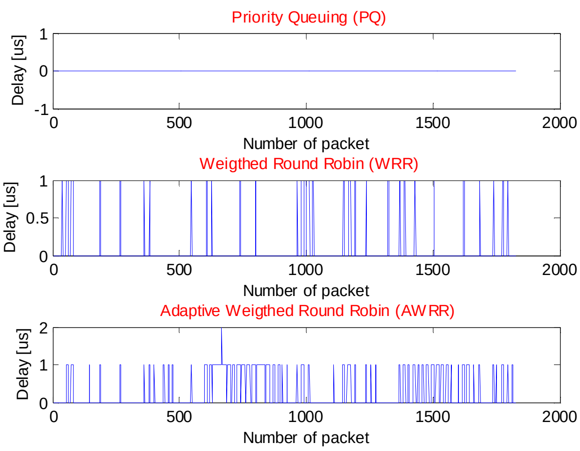

Figure 3. Delay of video packets.

Fig. 3 shows the performance of algorithms when it comes to video delay. PQ algorithm produces no delay as expected but at the cost of other types of packets as can be seen on next plots. AWRR algorithm reaches the point of 2µs only for one moment, apart from that it behaves similarly to WRR algorithm producing very low video delay.

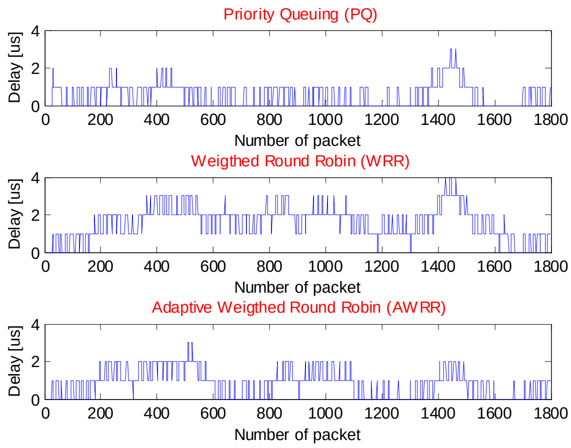

Figure 4. Delay of audio packets.

In Fig. 4, it may be observed that PQ and AWRR algorithms do not exceed 3µs, keeping the delay mostly in (0-2)µs range. WRR algorithm produces worst results comparing to the above.

In Fig. 5, the delay of www packets is shown. It has been observed that PQ produces good results when it comes to delay for video and audio but at the expense of www packets. One may notice rapid growth of delay from the start of simulation for PQ algorithm. The delay plot for PQ also has the highest maximum (see Table I).

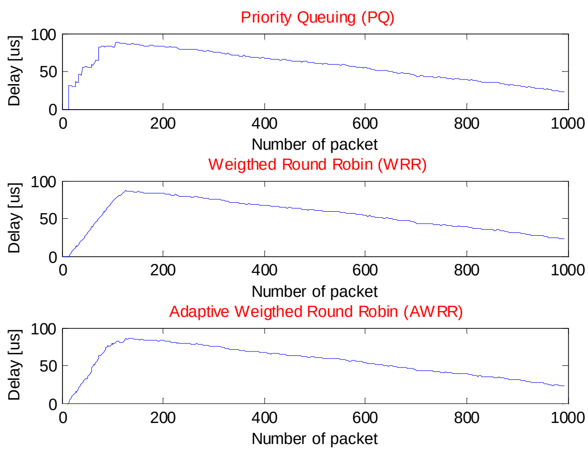

Figure 5. Delay of www packets.

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In Fig. 6, Fig. 7, and Fig.8., one can observe the performance of algorithms when it comes to jitter. PQ schedules video packets with no jitter, which is an expected behavior. This has however noticeable impact on jitter of the rest of the packets. PQ scheduling causes highest jitter in audio and www. This is because video packets were always sent first causing other types of packets to be placed in queue. AWRR and WRR perform similarly, with a slight advantage of the IWO based algorithm in video packets jitter.

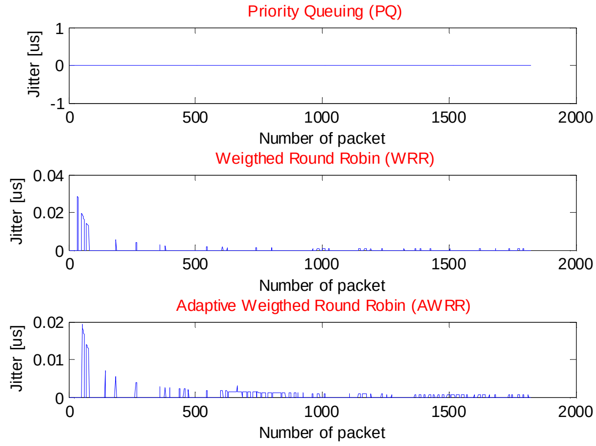

Figure 6. Jitter of video packets.

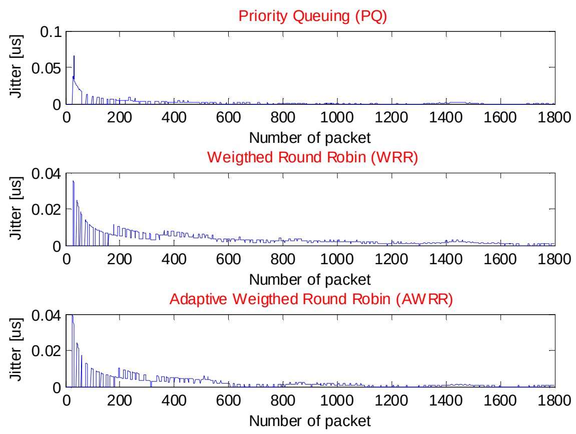

Figure 7. Jitter of audio packets.

TABLE I. MAXIMUM DELAY OF PACKETS

Maximum delay [µs]			
	PQ	WRR	AWRR
For all packets		87	86
For video packets	0	1	2
For audio packets	3	4	3
For www packets	89	87	86

TABLE II AVERAGE DELAY OF PACKETS

Average delay [µs]		
PQ	WRR	AWRR
12.4460	12.3479	12.2282

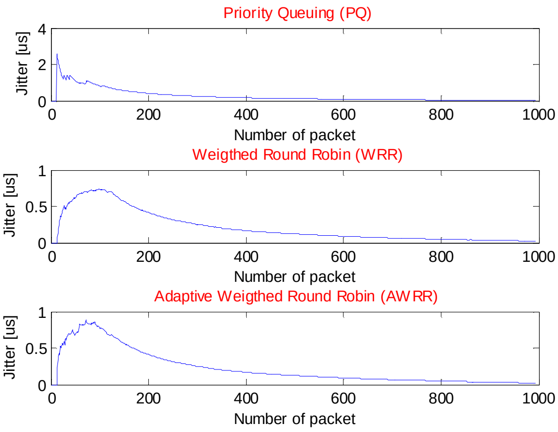

Figure 8. Jitter of www packets.

C. *Discussion*

The results obtained from the simulation show slight advantage of AWRR algorithm in packet queuing problem in comparison with basic priority scheduling algorithms.

As one can notice from Table I, the AWRR algorithm schedules packets with lower maximum delay without an increase in video and audio delays.

Comparing delay and jitter of audio packets for all algorithms (Fig. 4 and Fig. 7), we can say that the advantage of AWRR is noticeable. The results for www packets show the bad performance of PQ, especially when we take under consideration the jitter, and WRR or AWRR algorithms produce satisfying results.

Results of average delay presented in Table II show another advantage of AWRR algorithm for which the average is the lowest.

Discrepancies of results grow with the growing simulation time on the favor of AWRR algorithm.

VII. CONCLUSION

In general, the proposed algorithm AWRR produced good results confirmed by the simulation experiment, slightly outperforming the basic scheduling algorithms. However, while implementing more complex approaches, such as AWRR presented in this paper, one must have in mind much higher computational complexity and choose the right solution to the processing power of hardware.

In the nearer future, we plan to implement more metaheuristic algorithms, in particular the algorithms based on evolutionary approaches [8], as well as to extend the experimentation system by the implementation of the module allowing making the multistage experiments in automatic manner following the ideas presented in [9].

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