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Research on Dynamic Weight WFQ Algorithm of Wireless Networks

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Abstract. Excellent scheduling algorithms can optimize allocation and improve utilization of wireless resources. To improve QoS of wireless networks, this paper presents a Dynamic Weight-Weight Fair Queuing (DW-WFQ) algorithm with differentiated service that is suited to characteristics of wireless networks based on WFQ algorithm. The proposed algorithm adaptively adjusts the weights of queues according to the dynamical measurement of link state. It can fully make use of limited wireless network resources and improve the overall throughput of network.The simulation experiment results using OPNET software tool demonstrate that the proposed algorithm can improve the network throughput and reduce the average end-to-end delay, compared with WFQ algorithm.

Introduction

Nowadays, the wireless network is widely used in many fields. With the development of wireless network technologies, the wireless network will no doubt become a networking form used commonly. Besides supporting general data transmission, the wireless network also supports transmission of real-time multimedia traffic that is sensitive to some parameters such as delay. The wireless network is resource-limited, while users require the network system to utilize resource efficiently to meet different requirements of traffic on Quality of Service (QoS). Packet scheduling strategies determine the order of packet receiving service, which plays an irreplaceable role in providing QoS of traffic. Efficient scheduling algorithms can optimize allocation and improve utilization of wireless resources. Research on scheduling algorithm of wireless network is a little later than that of wire networks. Compared with wire networks, the wireless network has great specificities, which mainly demonstrates in the following aspects: limited bandwidth, location dependency as well as burst of error and high channel error rate.

Under this circumstance, if we want to introduce effective algorithms in no-error network into wireless networks, we need to improve the following two aspects: one is that when there is an error in the wireless network, how to adjust the bandwidth makes the existing resources be fully used and system throughput be improved; the other is that when the wireless network transfers from error state to normal state, how to adjust the bandwidth makes the traffic obtain its agreed service, which may be paused by network error, and provides QoS guarantee for different traffic. There are some existing algorithms for network scheduling, such as Traffic Dependent-Wireless Fair Queuing (TD-WFQ) algorithm [1] and Weighted Round Robin-Channel State Dependent Packet Scheduling (WRR-CSDPS) algorithm [2]. These algorithms consider the traffic differentiation, but not considering dynamic adjustment of queuing weight. Other scheduling algorithms, such as Wireless Deficit Round Robin (WDRR) algorithm [3], Dynamic Probabilistic Priority (DPP) algorithm [4] and Channel State Independent Wireless Fair Queuing (CS-WFQ) algorithm [5], consider about the effects of link state on scheduling algorithm and add queue weight adjustment, but not considering about the traffic differentiation.

WFQ scheduling algorithm is a mature scheduling algorithm in the wire networks. It adopts a mechanism that assigns packets to different queues according to priority. Each queue is assigned a weight. The queue with high weight has high priority to send packets. The application of WFQ algorithm to wireless network should combine with the characteristics of wireless networks. This paper presents a Dynamic Weight-Weight Fair Queuing (DW-WFQ) algorithm, which rightly starts from the characteristics of wireless link, and considers the effects of link state on scheduling algorithm based on WFQ algorithm and differentiate traffic. Simulation results show that the proposed algorithm can improve utilization of wireless resource and reduce the average end-to-end delay.

This paper is organized as follows: Section 2 introduces the dynamic weight scheduling algorithm and gives the scheduling model of the algorithm. In Section 3, a typical network simulation experiment using OPNET software tool is designed, which verifies the performance of the proposed algorithm. Section 4 draws conclusions.

Algorithm Description

Scheduling Model

The scheduling model of the proposed DW-WFQ algorithm fully considers about the link state information. The model shown in Fig. 1 is composed of link queues grouped by target nodes, weighted fair scheduler, wireless transceiver, link state watcher and weight scheduling controller. In Fig. 1, each link L_i ($i=1,2,\cdots,n$, is the index of the link) corresponds to two link queues, namely real-time traffic queue L_i^R and non-real-time traffic queue L_i^N . $W_i(t)$ is the current weight of the i-th link. The distribution coefficient of real-time traffic queue and non-real-time traffic queue, which correspond to the same destination node, are $\gamma(0<\gamma<1)$ and $1-\gamma$, respectively. The distribution coefficients of the same kind of link are the same. $W_i^R(t)=W_i(t)\times\gamma$ is the current weight of real-time traffic of the i-th link. $W_i^N(t)=W_i(t)\times(1-\gamma)$ is the current weight of non-real-time traffic of the i-th link and $W_i^R>W_i^N$. The scheduling strategy of weighted fair scheduler adopts WFQ scheduling algorithm. Link state watcher periodically monitors and reflects link state information and then provides it to weight adjust controller. Weight adjust controller performs adaptive adjustment of scheduling weight and bandwidth according to link state information.

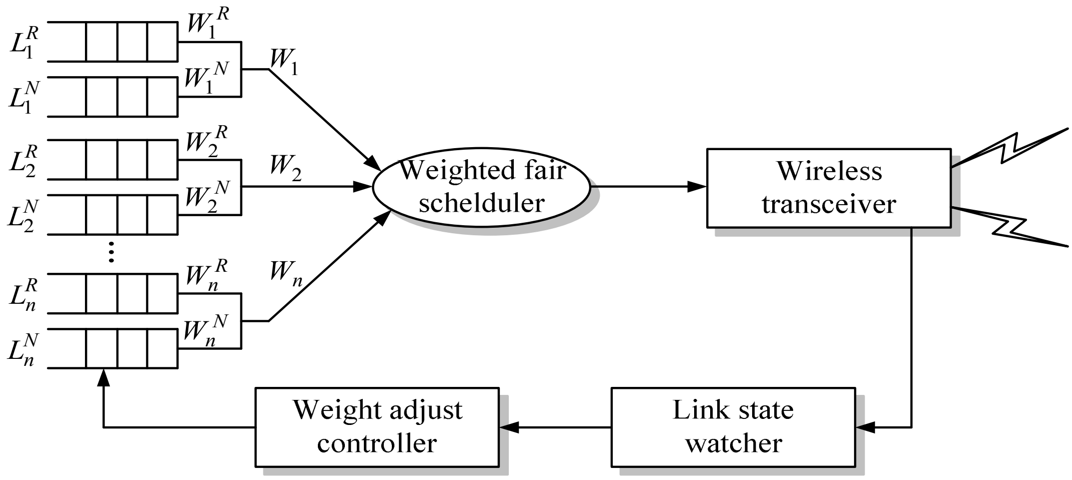

Figure 1.Scheduling model of DW-WFQ algorithm.

The scheduling process of the proposed DW-WFQ algorithm is described as follows: when all links in the network are in normal state and there is no idle link that means both real-time traffic queue and non-real-time traffic queue of the link are empty, weighted fair scheduler will use WFQ scheduling algorithm to schedule queues that correspond to all links. When the network is in the normal state and there is an idle link, weight adjust controller will adjust weight firstly, and then the scheduling can be performed. When a link in the network transfers from error state to normal state or from normal state to error state, the weight adjustment must be performed firstly, and then WFQ scheduling can be executed by weighted fair scheduler. Thus the bandwidth occupied by the idle link can be used by other links, i.e., the utilization of network resource is improved.

Link State Monitoring.

Packet scheduling algorithm of wire network does not need to consider about link state, while each link in the wireless network has location dependency on link state. The timely acquisition and feedback of wireless link state is the key issue to ensure the performance of scheduling algorithm [6].

As the error rate of wireless link can be obtained in real time, this paper uses error rate to denote link state. The error rate of link can be calculated by the ratio of number of error packets to total number of packets, or the ratio of error bytes to total bytes. This paper uses the former error rate. When the error rate is less than 50%, we can think that this link is in good state, otherwise in bad state.

In the simulation experiment, the two-state Markov model is used to simulate the wireless link. If the channel is in bad state, it is a waste of resources to reuse it. Therefore, in the proposed DW-WFQ algorithm, the base station prioritily sends data to links in good state based on the monitoring result from link state watcher. So the proposed algorithm can improve utilization of wireless network resource.

Weight Adjustment Algorithm.

In order to control QoS of different traffic, the proposed DW-WFQ algorithm assigns different scheduling weights to different nodes. The weight is used to control bandwidth allocation proportion when nodes access media.

As $W_i(t)$ ($i=1,2,\cdots,n$) is the current weight of the i-th link, the current weight that corresponding to all the no-error links in the network can be denoted as $\sum_i W_i(t)$. $B_s(t)$ is the current bandwidth of the system, then we can achieve the bandwidth b_j when the link j is being scheduled:

$$b_j = [W_j(t) / \sum_i W_i(t)] \times B_s(t)\,, \tag{1}$$

where $W_i(t) = W_{i,e}(t) + W_{i,n}(t)$, $W_{i,n}(t)$ denotes the weight of the i-th link that has not been affected by network error, and $W_{i,e}(t)$ represents the weight of the i-th link that has been affected by network error. The adjustment coefficient λ_i (0< λ_i <1) is used to adjust the weight of normal link, while the weight of error link is maintained unchanged. Assume that $W^*{}_{i,n}(t)$ and $W^*{}_{i,e}(t)$ are respectively weights of normal link and error link after resume adjustment process, then the adjustment formula is as follows:

$$\begin{cases} W^*{}_{i,n}(t) = W_{i,n}(t) \times \lambda_i \\ W^*{}_{i,e}(t) = W_{i,e}(t) \end{cases} \tag{2}$$

Calculation of Resume Adjustment Time

In order to measure and adjust dynamically, it is crucial to determining the resume adjustment time. Suppose that failure time of the i-th queue is T_i and resume adjustment time is T_i^*. During the period, the service that queue received is S_i^*. If there is no error in the queue, the service that the i-th queue receive in the period $(T_i + T_i^*)$ is S_i, so there should be $S_i = S_i^*$. Since $S_i = b_i \times (T_i + T_i^*)$ and $S_i^* = b_i^* \times T_i^*$, we can obtain the following by (1):

$$[W_{i,e}(t) / \sum_j W_j(t)] \times B_s(t) \times (T_i + T_i^*) = \{W_{i,e}(t) / [\sum_j^{j\neq i} W_j(t) \times \lambda_j + W_{i,e}(t)]\} \times B_s^*(t) \times T_i^*\,. \tag{3}$$

As $B_i(t) = B_i^*(t)$, we have:

$$T_i^* = T_i [\sum_j^{j\neq i} W_j(t) \times \lambda_k + W_{i,e}(t)] / [\sum_j^{j\neq i} W_j(t) \times \lambda_k \times (1-\lambda_k)]\,. \tag{4}$$

Simulation Results

Simulation Environment and Parameters Setting

A centralized wireless network is designed in the simulation experiment, namely there is a base station or a wireless access point (AP) in the network. In this kind of network, communications among wireless nodes and that between wireless node and wire network are switched by base station, which is the bottleneck of data transmission. OPNET 10.0 is selected as the network simulation tool. Simulation time is set to 10*min*, and simulated network topology is shown in Fig. 2. In the network, bandwidth of wire link is 100*Mbps* and delay is 15*ms*. The transmitter S_1 and S_2 send data to wireless terminals H_i ($i=1,2,\cdots,10$) in the way of FTP and CBR, respectively.

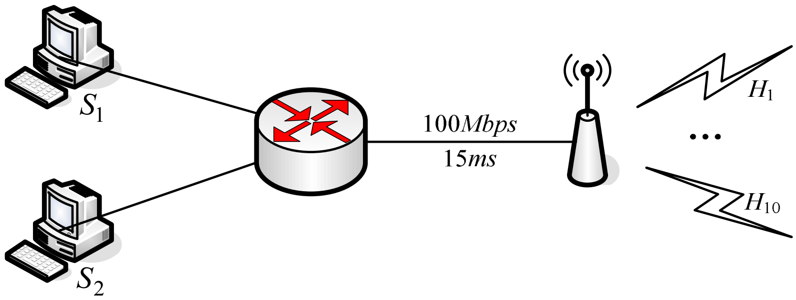

Figure 2.Topology of simulation network.

Analysis of Simulation Results

The experiment compares the proposed DW-WFQ algorithm with WFQ algorithm from two aspects of throughput and average end-to-end delay. The simulation results are shown in Fig. 3 and Fig. 4.

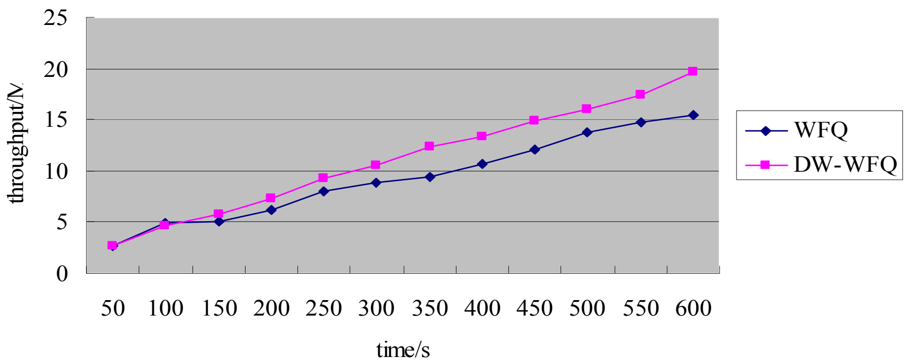

Figure 3.Comparison of throughput.

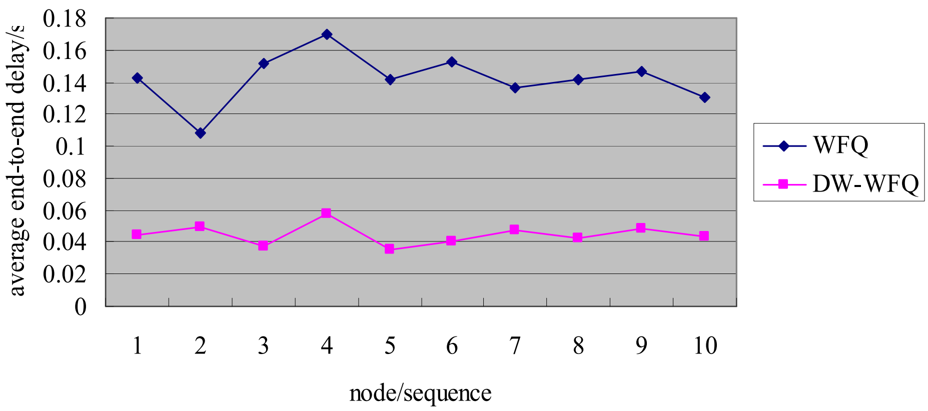

Figure 4.Comparison of average end-to-end delay of CBR traffic.

Fig. 3 shows the difference between two algorithms in the aspect of system throughput. At the moment of 60*s* of the simulation time, there occurs error in the channel. Before the moment, there is little difference between two kinds of algorithms. The reason is that the proposed DW-WFQ algorithm degenerates into WFQ algorithm when there is no error in the channel. After the moment, the proposed DW-WFQ algorithm has higher throughput than WFQ algorithm because the proposed DW-WFQ algorithm can improve the utilization efficiency of the system bandwidth by detecting channel errors and adjusting the weights of queues.

Fig. 4 illustrates the average end-to-end delay of CBR traffic of two algorithms. From Fig. 4, it is obvious that the average end-to-end delay of wireless node using the proposed DW-WFQ algorithm is lower than that of WFQ algorithm and keeps about 0.05*s*. The proposed DW-WFQ algorithm can differentiate traffic to guarantee the delay characteristic so that it is more suitable for real-time traffic regime.

Conclusions

The scheduling strategies determine the order of packet receiving service, which plays an irreplaceable role in providing QoS of traffic. Excellent scheduling algorithms can optimize radio resource allocation and improve utilization of wireless resources. According to characteristics of wireless network, this paper presents a DW-WFQ algorithm based on WFQ algorithm and traffic differentiation. The proposed DW-WFQ algorithm adaptively adjusts the weights of queues according to dynamically measuring link state, which improves the utilization of wireless network resources and the overall throughput of the network. Simulation results of a kind of typical network demonstrate the improvement of the proposed algorithm on WFQ algorithm in aspects of network throughput and average end-to-end delay.

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