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Token Based Fair Queuing Algorithms for Wireless Networks

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Abstract

Token Based Fair Queuing (TBFQ) algorithm has been proposed for single carrier Time Division Multiple Access (TDMA) systems, to suit WINNER Orthogonal Frequency Division Multiple Access (OFDMA) air-interface. This algorithm takes Quality of Service (QoS) attributes such as priorities, interflow fairness, and time bound constraints into account. We use a token-based scheduler to determine which packet should be scheduled to transmit in the next frame. By selecting the user terminals (UTs) in a certain prioritized manner derived from QoS attributes, the performance of the UTs, suffering from high interference, can be improved. In This paper, TBFQ algorithm has been simulated in a multicell environment in the presence of intercell interference by comparing with reference Score Based (SB) algorithm. The simulation results show that the presented algorithm provide a better fairness at a lower implementation at all level implementation complexity while simultaneously achieving comparable network utilization by considering time bound associated to particular packets.

Keywords: QoS, scheduling, Fairness, time bound.

1. Introduction

In recent years there has been tremendous growth in the wireless networking industries. With the increasing usage of wireless networks in both indoor and outdoor computing environments, the issue of providing fair channel access among multiple contending packet flow over a scarce and shared wireless channel has come to the fore[1]. Recently, a number of algorithms have been proposed for adapting fair queuing to the wireless domain [2-4]. However, there has not been any work to precisely characterize the desired service model in terms of a wireless fair service and to define unified wireless fair queueing architecture to achieve wireless fair service [5]. In addition, the failure of traditional fluid fair queueing in the presence of location-dependent channel error [6] and the compensation model flows that perceive channel error and the trade-off between full separation and compensation, and its impact on fairness of channel access [7]. Wireless fair queueing (WFQ) is an approximation algorithm designed for providing fairness and delay bound properties and delay bound properties to emulate the generalized processor sharing (GPS) scheme, which is based on a fluid model but cannot be practiced in the real world, at the packet level. Many other packet fair queuing algorithms, such as start-time fair queuing [8], self-clocked fair queuing, and worst-case fair weighted fair queuing are also proposed to approximate the service of GPS [9]. Consequently, the fair queueing algorithms proposed in literature for wire-line networks do not apply directly to wireless networks. In a related work, the proposed WFQ algorithm that addressed a number of the issues raised above. The objective of this work was to simulate a WFQ based Token-based packet scheduling scheme classify packets into time deadline and non time deadline packets. Each category packets are inserted into two queues first preference is for time deadline packets then non time deadline packets. This scheme is investigated through extensive simulation considering system parameters. The rest of the paper is organized as follows. In Section II, the system model and TBFQ algorithm is described in detail along with its parameter selection and methods of fairness assessment. The simulation parameters and Simulation results are presented in Section III. Section IV concludes the work.

2. System Model

In wireless networks, strict scheduling schemes may not seem appropriate as flows cannot a priori determine their exact behaviour as most schedulers would require. The environment of wireless scheduling requires soft handling of packets [10] this is the philosophy behind token-based fair queueing (TBFQ). Soft quality of service (QoS) provision of a session to be the graceful acceptance of traffic profile violation when excess bandwidth is available provided the user terminal (UT) does not exceed its bandwidth allocation in the long term. This prevents sudden degradation of quality of service experienced by the end user as a result of traffic profile violations. TBFQ penalizes violating traffic less severely as it is able to service a packet, which might otherwise be discarded by per flow policing mechanism, by distributing unused bandwidth from other connections. A work conserving scheduler is never idle while there are packets waiting to be transmitted in the service queues [11]. On the other hand, a non-work conserving scheduler may be idle even if their packets waiting to be served. In a wireless network it may be better to postpone a terminal from transmitting if the channel condition is poor; this gives the opportunity for other terminals to utilize the bandwidth while their channel condition may be better [12]. The postponing of scheduling service due to impaired channel condition can turn a work conserving algorithm to a non-work conserving one. The parameters of the algorithm are defined with respect to a packet based system. Each frame in a TBFQ can be considered as a round in a round robin based system except that in each frame the order of service will change according to the priorities assigned to the users[13]. A round is generally defined as having varied time intervals and the length of which depend on the completion of servicing all the flows in turn in the system. Frames are intervals with fixed time period [14]. The structure for TBFQ in the downlink is shown in Fig. 1.

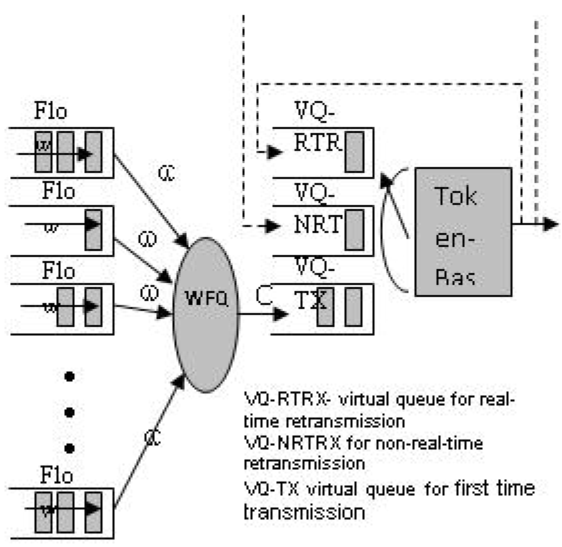


Fig. 1 The TBFQ queueing model of proposed packet scheduling scheme

Consider l is the size of the packet that is checked by the token-based scheduler, is the jth packet of flow i which is scheduled in the next frame, Li is the total length of the scheduled packets of flow i. That is Li = ∑ jl ji, Remained slots available for scheduling = C - ∑i ┌L i┐ Assume that there are C slots available for downlink traffic each frame, each flow i maintains a token value ti, The token value of every session i has fixed token incremental rate ri, the unit of ri is slots / frame.

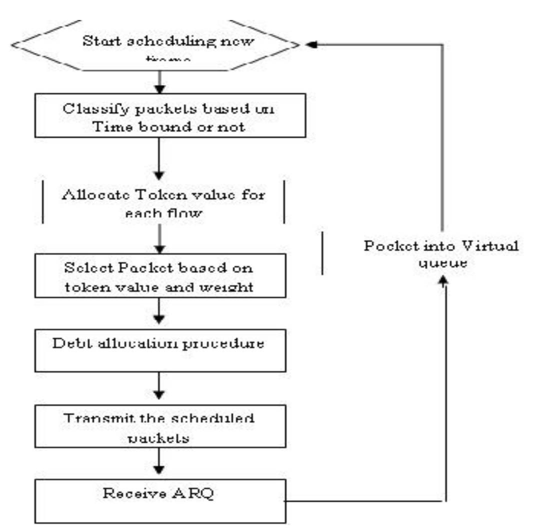
At each beginning of a frame, the token value of session i is increased by ri slots. The work of updating the token value of every flow at the beginning of a frame is done by the token generator.

When a packet of flow i with size l (normalized to slots) is scheduled to transmit, it must take the token value equal to the amount of the size of the packet away. And the number of slots available for scheduling is also decreased by Li is the total length of the scheduled packets of flow i and with size l is scheduled ti□ti-1, L+=1, remained slot = C - ∑i ┌L i┐. There should be an upper bound of the token value Ti then frame starts ti□max (ti+ri, Ti) for each flow I. We can regarded ri as the protected capacity of flow i. The configuration of ri can affect the system performance significantly. The basic principal of scheduling is assumed is as follows.

[1] The packet has sufficient token value to transmit it has the higher priority, or it has the lower priority

[2] For the packets with the same priority, the scheduling order is according to the order in TBFQ scheduler

The flow chart of all procedures of the token-based slot scheduler is shown in Fig. 2.



The selection procedure and debt allocation procedure are given below.

Pack selection procedure (Fig-3)

system_capacity {
remained_slot ← system_capacity;
for (each flow j) {$block_j = 0$}
for (each virtual queue, from highest priority to lowest priority)
While (packet not checked in the virtual queue)
{ i ← the flow the packet belong to;
l← the size of the checked packet;
if (remained_slot ≥ $\lceil L_i + l \rceil - \lceil L_i \rceil$ and $l \leq t_i$ and $block_i$ = = 0)
{ schedule this packet in the next frame;
Remaind_slot - = $\lceil L_i + l \rceil - \lceil L_i \rceil$;
T_i - = l;
} else
$block_i$ =1;
}}
Debt-allocation-procedure (remained_slot);
}

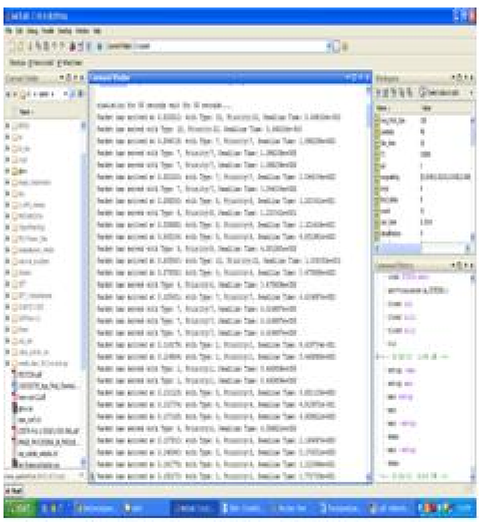


Fig. 4 Statistics of the debt allocation

Debt allocation procedure (Fig-5)

Debt_allocation_procedure (remained_slot) {
for(each flow j)
$block_j$ ←0;
for (each virtual queue, from the highest priority to the lowest priority){
while (packets not checked and not scheduled in the virtual queue){
i←the flow the packet belong to;
l ← the size of the packet;
if (remained_slot ≥ $\lceil L_i + l \rceil - \lceil L_i \rceil$ and $block_i$!=1) {
schedule the packet in the next frame
debt←-1*max(t_i-l, -l);
t_i - = l;
remained_slot - = $\lceil L_i + l \rceil - \lceil L_i \rceil$;
for(all real-time flows k) {

$$t_k = max\left(t_k + \frac{w_k * debt}{\sum_{j\varepsilon RT} w_j}, T_k\right);$$

}} else
$Block_i$ ←1}}}

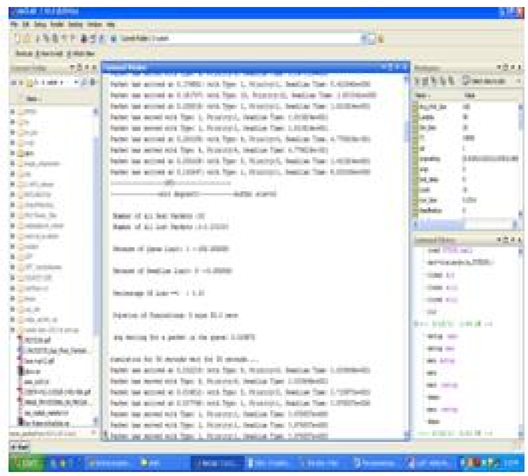


Fig. 6 Statistics of the packet scheduling

3. System simulation results

Parameter Used Value/Model Signal bandwidth: 3kHz Scheduler TBFQ Frame duration Maximum of 1 second Traffic model Payload data model Packet size 64 kb Packet drop criterion Maximum 1 second Simulation Time 50 seconds Simulation Tool Matlab .

Table 1. Summary of Simulation Parameters

Parameter	Used Value/Model
Signal bandwidth:	3kHz
Scheduler	TBFQ
Frame duration	Maximum of 1 second
Traffic model	Payload data model
Packet size	64 kb
Packet drop criterion	Maximum 1 second
Simulation Time	50 seconds
Simulation Tool	Matlab

In this section, the TBFQ scheduling scheme is investigated in the presence of interference at the system level. The results of the scheduling decisions are shown under performance under varied network loading.

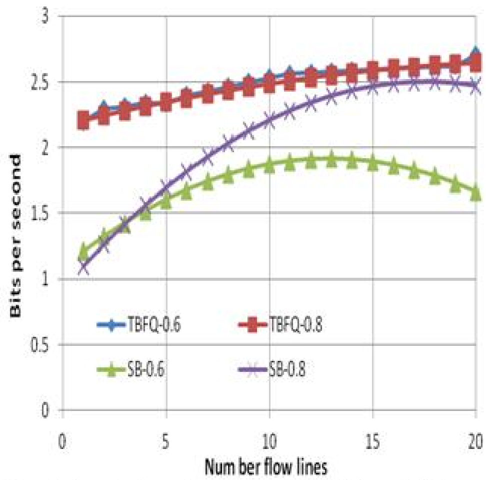


Fig. 7 Spectral performance of TBFQ and SB as a function of number of flow lines at activity factor of 0.6 and 0.8

Fig. 7 shows the comparison of spectral efficiency of the TBFQ algorithm with that of scored based when the number of users is varying. Two levels of interference activity factor (0.6 and 0.8) are shown. It is seen that for low loading levels, TBFQ outperforms scored based.

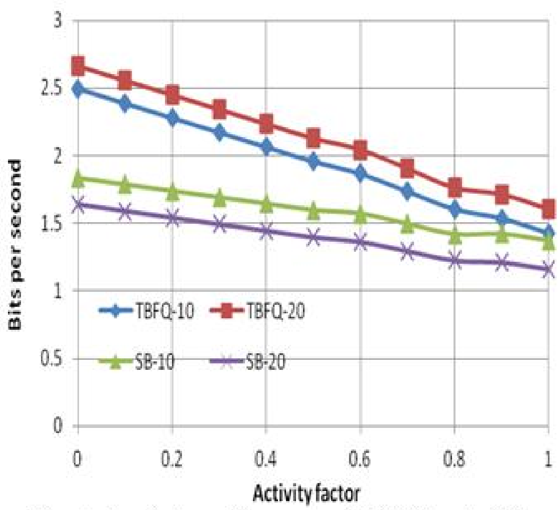


Fig. 8 Spectral performance of TBFQ and SB as function of activity factor at flow lines of 10 and 20.

This difference is due to the opportunistic nature of scored based as it tries to take advantage of multiuser diversity which is not available at low loading levels. This becomes more evident at medium to high loading when scored based outperforms ATBFQ when there are more flow lines (users). It tries to maximize the spectral efficiency by selecting users with the best channel conditions whereas TBFQ tires to maintain fairness by distributing resources to deprived users with bad channel condition. This will become more evident when the performance results for queuing delay.

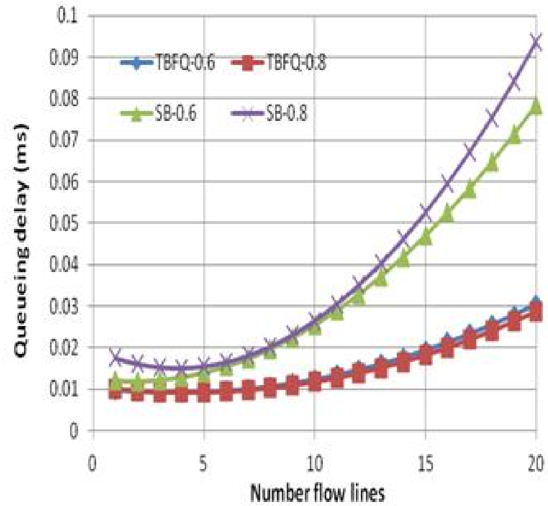


Fig. 9 Effect of number of flow lines on queueing delay for TBFQ and SB at activity factor of 0.6 and 0.8.

Fig.9 and Fig. 10 show the effect of number of flow line and activity factor on queueing delay in milli second for TBFQ and SB respectively.

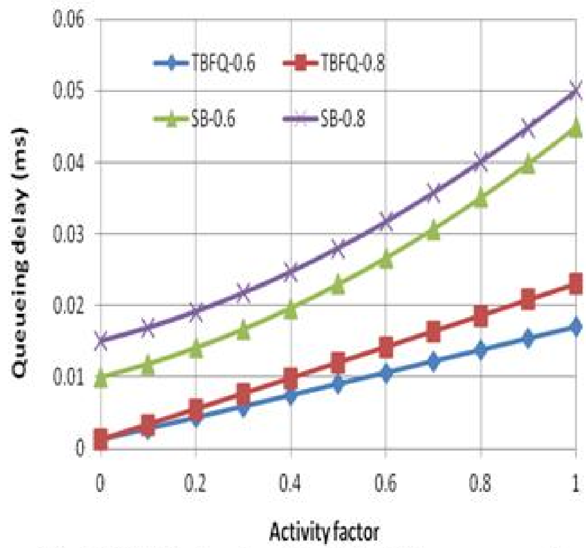


Fig. 10 Effect of value of activity factor on queueing delay for TBFQ and SB at flow line of 10 and 20.

The performance of TBFQ is compared to that of SB at all activity factors the TBFQ shown outperforms than that of SB. It is observed for high loading that although the performance degrades for both TBFQ and SB as expected, TBFQ slightly increased but in SB shows more drastic delay. This is explained due to the fact that this delay is only considered for transmitted packets. Thus as TBFQ tries to maintain

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fairness at high loading, it incurs high queuing delays.

4. Conclusion

TBFQ is well designed algorithms with low complexity offering fairness among and potentially differentiation between different data-flows is important in the evolution of networks. It is also shown how the TBFQ scheduler can significantly improve the performance for cell edge users in terms of throughput and packets distribution. The developed TBFQ algorithm provides short and long term fairness among all flows which perceive a clean channel with bounded channel error, optimal schedulable region by decoupling delay, weights and support both delay sensitive and error sensitive flows.

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