Studies on the Short Term Fairness Properties of Joint Scheduler

Fumio Ishizaki, Nanzan University, Japan

ABSTRACT

Since the utilization of multiuser diversity in wireless networks can increase the information theoretic capacity, much attention has been paid to packet schedulers exploiting multiuser diversity. However, it is known if there exists a tradeoff between the information theoretic capacity and fairness achieved by schedulers exploiting multiuser diversity. Therefore, the authors consider the fairness of the schedulers exploiting multiuser diversity as well as their information theoretic capacity. Among schedulers exploiting multiuser diversity, the one-bit feedback fair scheduler is considered an attractive choice due to its good balance between the capacity and fairness. This paper considers a joint scheduler which incorporates the weighted round-robin scheduling into the one-bit feedback fair scheduling. It is expected that by incorporating the round-robin scheduling into the one-bit feedback fair scheduling, the short term fairness of the scheduler is greatly improved. Considering the statistical time-access fairness index (STAFI) as a measure of short term fairness, the authors study the short term fairness properties provided by the joint scheduler. The effects of the threshold of the scheduler on the STAFI are investigated. The threshold of the scheduler strongly affects its short term fairness properties.

Keywords: Joint Scheduler, Multiuser Diversity, One-Bit Feedback Fair Scheduler, Short Term Fairness, Statistical Time-Access Fairness Index

INTRODUCTION

Since bandwidth is one of scarce resources in wireless networks, packet scheduler for efficient bandwidth utilization is a key component to the success of quality-of-service (QoS) guarantees in wireless networks. One technique for efficient bandwidth utilization in time-varying wireless channels is to exploit multiuser diversity (Kopp & Humblet, 1995). Multiuser diversity is a diversity existing between the channel states of different users. Multiuser diversity comes from the fact that the wireless channel state processes of different users are usually independent for the same shared medium. Since exploiting multiuser diversity in wireless networks can increase the information theoretic capacity of the overall system, much attention has been paid to packet schedulers exploiting multiuser diversity (e.g., Florén et al., 2003; Ishizaki & Hwang, 2007; Kim & Han, 2007; Wu & Negi, 2005). However, it is known that there exists a tradeoff between the information theoretic capacity and fairness achieved by schedulers exploiting multiuser diversity (Yang et al., 2009).
Therefore, we should consider the fairness of schedulers exploiting multiuser diversity as well as their information theoretic capacity.

The fairness of scheduler is classified into short term fairness and long term fairness (Hwang & Ishizaki, 2010b; Tan et al., 2008). Short term fairness indicates the ability of the scheduler on how equally it can distribute network resources (e.g., service times) over multiple mobile stations (MSs) in a finite observation period. On the other hand, long term fairness indicates the ability of the scheduler on how equally it can distribute network resources over multiple MSs in an infinite observation period. While long term fairness governs the long run performances such as long run average throughput of individual MSs, short term fairness greatly affects the packet level performances such as delay and loss probability of individual MSs. Since the packet level performances of individual MSs are basic measures of QoS, it is important to examine the short term fairness of scheduler in terms of QoS guarantees.

As a measure of short term fairness for wireline networks, the proportional fairness index is usually considered. The proportional fairness index focuses on the service discrepancy in bits between two flows over any time interval during which the two flows are continuously backlogged. The proportional fairness index is expressed as

\[ \left| \frac{\bar{t}^{(i)}(t_1, t_2)}{\phi^{(i)}} - \frac{\bar{t}^{(j)}(t_1, t_2)}{\phi^{(j)}} \right| \leq c^{(i,j)} \]

where \( \bar{t}^{(i)}(t_1, t_2) \) denotes the service in bits that flow receives during \([t_1, t_2] \), \( \phi^{(i)} \) denotes the assigned weight for flow \( i \) and \( c^{(i,j)} \) is a constant which may depend on \( i \) and \( j \). Unfortunately, for the following two reasons, the proportional fairness index for wireline networks is not suitable for wireless networks. First, the proportional fairness index considers the hard deterministic guarantee, and it does not take randomness inherent in the wireless channel conditions into account. Second, the proportional fairness index considers fairness of users’ throughputs rather than channel access times, although users can transmit at different rates depending on their current channel quality in wireless networks. Liu et al. (2003) then consider modifications to the proportional fairness index for short term fairness index in wireless networks. By considering the service in time (instead of the service in bits) and a statistical fairness guarantee (instead of the hard deterministic fairness guarantee), they propose a statistical time-access fairness index (STAFI) defined as

\[
P\left( \left| \frac{\bar{a}^{(i)}(t_1, t_2)}{\phi^{(i)}} - \frac{\bar{a}^{(j)}(t_1, t_2)}{\phi^{(j)}} \right| \geq x \right) \leq f^{(i,j)}(x)
\]

where \( \bar{a}^{(i)}(t_1, t_2) \) denotes the service in time that flow \( i \) receives during \([t_1, t_2] \), \( \phi^{(i)} \) denotes the assigned weight for flow \( i \), and \( f^{(i,j)}(x) \) is some function which may depend on \( i \) and \( j \).

Among schedulers exploiting multiuser diversity, the one-bit feedback fair scheduler is considered as an attractive choice due to its good balance between the capacity and fairness (and also the ease of implementation) (Diaz et al., 2006; Hwang & Ishizaki, 2008; Somekh et al., 2007). It is reported that the one-bit feedback fair scheduler can achieve a relatively good capacity if the threshold value is appropriately determined (Hwang & Ishizaki, 2008). Since the normalized SNR values are i.i.d. (independent and identically distributed) among all MSs, the one-bit feedback fair scheduler provides the same long run average access-time to all MSs, i.e., achieves the ideal long term fairness. However, the short term fairness achieved by the one-bit feedback fair scheduler (Ishizaki, 2011a, 2011b) may not be satisfactory, when strict short term fairness is needed.

In this paper, we consider a joint scheduler which incorporates the weighted round-robin scheduling into the one-bit feedback fair
Related Content

Exploration on SA Query Mechanism in IEEE 802.11w
[www.igi-global.com/article/exploration-on-sa-query-mechanism-in-ieee-80211w/130901?camid=4v1a](www.igi-global.com/article/exploration-on-sa-query-mechanism-in-ieee-80211w/130901?camid=4v1a)

A Mobile Intelligent Agent-Based Architecture for E-Business
[www.igi-global.com/chapter/mobile-intelligent-agent-based-architecture/28738?camid=4v1a](www.igi-global.com/chapter/mobile-intelligent-agent-based-architecture/28738?camid=4v1a)
Emerging Trends in Digital Libraries: Mobile Technology and Mobile Learning
[www.igi-global.com/chapter/emerging-trends-in-digital-libraries/105681?camid=4v1a](www.igi-global.com/chapter/emerging-trends-in-digital-libraries/105681?camid=4v1a)

A Semantic Approach to Designing Information Services for Smart Museums
[www.igi-global.com/article/a-semantic-approach-to-designing-information-services-for-smart-museums/180292?camid=4v1a](www.igi-global.com/article/a-semantic-approach-to-designing-information-services-for-smart-museums/180292?camid=4v1a)