Minimizing the Queue Overflow Probability using Wireless Scheduling Algorithm

Kammilla Anand[1] Mr. S. Muni Kumar[2]
[1]Student [2]Assistant Professor
[1,2]Department of Computer Applications
[1,2]KMM Institute of PG Studies, Tirupati, India

Abstract— In this paper, we are interested in wireless scheduling algorithms for the downlink of a single cell that can minimize the queue-overflow probability. Specifically, in a large-deviation set- ting, we are interested in algorithms that maximize the asymptotic decay rate of the queue-overflow probability, as the queue-over-flow threshold approaches infinity. We first derive an upper bound on the decay rate of the queue-overflow probability over all scheduling policies. We then focus on a class of scheduling algorithms collectively referred to as the "algorithms." For a given, the -algorithm picks the user for service at each time that has the largest product of the transmission rate multiplied by the backlog raised to the power . We show that when the overflow metric is appropriately modified, the minimum-cost-to-overflow under the -algorithm can be achieved by a simple linear path, and it can be written as the solution of a vector-optimization problem. Using this structural property, we then show that when approaches infinity, the -algorithms asymptotically achieve the largest decay rate of the queue-overflow probability. Finally, this result enables us to design scheduling algorithms that are both close to optimal in terms of the asymptotic decay rate of the overflow probability and empirically shown to maintain small queue-overflow probabilities over queue-length ranges of practical interest.
Keywords: Wireless Scheduling Algorithm, Asymptotically Optimal Algorithms, Cellular System, Large Deviations, Queue-Overflow Probability

I. INTRODUCTION

LINK scheduling is an important functionality in wireless networks due to both the shared nature of the wireless medium and the variations of the wireless channel over time. In the past, it has been demonstrated that by carefully choosing the scheduling decision based on the channel state and/or the demand of the users, the system performance can be substantially improved (see, e.g., the references in [2]). Most studies of scheduling algorithms have focused on optimizing the long-term average throughput of the users or, in other words, stability. Consider the downlink of a single cell in a cellular network. The base-station transmits to users. There is a queue Q_i associated with each user $i = 1, 2, \ldots, N.$ Due to interference, at any given time, the base-station can only serve the queue of one user. Hence, this system can be modeled as a single server serving N queues. Assume that data for user arrives at the base-station at a constant rate . Furthermore, assume a slotted model, and in each time-slot the wireless channel can be in one of M states. In each state $m = 1, 2, \ldots, M.$, if the base-station picks user i to serve, the corresponding service rate is F_m^i. Hence, at each time-slot, Q_i increases by λ_i, and if it is served and the channel is at state m, Q_i decreases by F_m^i. We assume that perfect channel information is available at the base-station. In a stability problem [3]-[5], the goal is to find algorithms for scheduling the transmissions such that the queues are stabilized at given offered loads. An important result along this direction is the development of the so-called "throughput-optimal" algorithms [3]. A scheduling algorithm is called throughput-optimal if, at any offered load under which any other algorithm can stabilize the system, this algorithm can stabilize the system as well. It is well known that the following class of scheduling algorithms are throughput-optimal [3]-[5]: For a given $\alpha \geq 1,$ the base-station picks the user for service at each time that has the largest product of the transmission rate multiplied by the backlog raised to the power α. In other words, if the channel is in state m , the base-station chooses the user i with the largest $(Q_i)^\alpha F_m^i$. To emphasize the dependency on , in the sequel we will refer to this class of throughput-optimal algorithms as α- algorithms. While stability is an important first-order metric of success, for many delay-sensitive applications, it is far from sufficient. In this paper, we are interested in the probability of queue overflow, which is equivalent to the delay-violation probability under cer- tain conditions. The question that we attempt to answer is the following: Is there an optimal algorithm in the sense that, at any given offered load, the algorithm can achieve the smallest probability that any queue overflows, i.e., the smallest value of $\mathbf{P}[\max_{1 \leq i \leq N} Q_i(T) \geq B]$, where B is the overflow threshold? Note that if we impose a quality-of-service (QoS) constraint on each user in the form of an upper bound on the queue-overflow probability, then the above optimality condition will also imply that the algorithm can support the largest set of offered loads subject to the QoS constraint. Unfortunately, calculating the exact queue distribution is often mathematically intractable. In this paper, we use large-deviation theory [11], [12] and reformulate the QoS constraint in terms of the asymptotic decay rate of the queue-overflow probability as B approaches infinity. In other words, we are interested in finding scheduling algorithms that can achieve the smallest possible value of

$$\limsup_{B \to \infty} \frac{1}{B} \log \mathbf{P}\left[\max_{1 \leq i \leq N} Q_i(T) \geq B\right].$$

Our main results are the following. We show that there exists an optimal decay rate I_{opt} such that for any scheduling algorithm

$$\liminf_{B\to\infty} \frac{1}{B} \log\left(\mathbf{P}\left[\max_{1\le i\le N} Q_i(0) \ge B\right]\right) \ge -I_{\text{opt}}.$$

Furthermore, for α-algorithms

$$\lim_{\alpha\to\infty} \limsup_{B\to\infty} \frac{1}{B} \log \mathbf{P}_0^{\alpha}\left[\max_{1\le i\le N} Q_i(T) \ge B\right] \le -I_{\text{opt}}$$

. where $\mathbf{P}_0^{\alpha}$ is the probability measure for the α-algorithm. Hence, when α approaches infinity, the α-algorithms asymptotically achieve the largest decay rate of the queue-overflow probability.

II. Literature Survey

The motto of the project is minimizing the queue-overflow probability on wireless networks based on Scheduling Algorithms. In this paper, we are interested in wireless scheduling algorithms for the downlink of a single cell that can minimize the queue-over-flow probability. Specifically, in a large-deviation set- ting, we are interested in algorithms that maximize the asymptotic decay rate of the queue-overflow probability, as the queue-over-flow threshold approaches infinity. We first derive an upper bound on the decay rate of the queue-overflow probability over all scheduling policies. We then focus on a class of scheduling algorithms collectively referred to as the "algorithms." For a given , the -algorithm picks the user for service at each time that has the largest product of the transmission rate multiplied by the backlog raised to the power . We show that when the overflow metric is appropriately modified, the minimum-cost-to-overflow under the -algorithm can be achieved by a simple linear path, and it can be written as the solution of a vector-optimization problem. Using this structural property, we then show that when approaches infinity, the -algorithms asymptotically achieve the largest decay rate of the queue-overflow probability. Finally, this result enables us to design scheduling algorithms that are both close to optimal in terms of the asymptotic decay rate of the overflow probability and empirically shown to maintain small queue-overflow probabilities over queue-length ranges of practical interest.

A. An Upper Bound on the Decay Rate of the Overflow Probability

In this section, we first present an upper bound I_{opt} on $I_0(\boldsymbol{\lambda})$ [defined in (5)] under a given offered load $\boldsymbol{\lambda}$. This value I_{opt} bounds from above the decay rate for the overflow probability of the stationary backlog process $\boldsymbol{Q}(t)$ over all scheduling policies. For every probability vector $\boldsymbol{\phi} \in \mathcal{P}_M$, define the following optimization problem:

$$w(\boldsymbol{\phi}) \triangleq \inf_{[\tilde{\gamma}_m^i]} \max_{1\le i\le N} \left[\lambda_i - \sum_{m=1}^{M} \phi_m \tilde{\gamma}_m^i F_m^i\right]^+$$

$$\text{subject to} \quad \sum_{i=1}^{N} \tilde{\gamma}_m^i = 1 \text{ for all } m = 1,\ldots,M$$

$$\tilde{\gamma}_m^i \ge 0 \text{ for all } i = 1,\ldots,N \text{ and } m.$$

Here, $\tilde{\gamma}_m^i$ can be interpreted as some long-term fraction of time that user i is served when the channel state is m. Hence, if the channel-rate process is given by $\boldsymbol{s}(t) = \boldsymbol{\phi} t$, then $\left[\lambda_i - \sum_{m=1}^{M} \phi_m \tilde{\gamma}_m^i F_m^i\right]^+$ denotes the long-term growth rate of the backlog of user i.

III. Methodology

For the above problem, it is natural to use the large-deviation theory because the overflow probability that we are interested in is typically very small [1], [2]. Large-deviation theory has been with success applied to wireline networks (see, e.g., [3]–[5]) and to wireless planning algorithms that solely use the channel state to create the planning selections [2]–[4]. However, once applied to wireless planning algorithms that additionally use the queue-length to create planning selections (e.g., the -algorithms), this approach encounters a significant amount of technical difficulty. Specifically, in order to apply the large-deviation theory to queue-length-based scheduling algorithms, one has to use sample-path large deviation and formulate the problem as a multidimensional calculus-of-variations (CoV) problem for finding the "most possible path to overflow." The decay rate of the queue-overflow probability then corresponds to the cost of this path, which is referred to as the "minimum cost to overflow." Unfortunately, for many queue-length-based planning algorithms of interest, this multidimensional calculus-of-variations problem is very difficult to solve. In the literature, only some restricted cases have been solved: Either restricted problem structures are assumed (e.g., symmetric users and ON–OFF channels [3]), or the size of the system is very small (only two users) [4]. In this paper, to circumvent the difficulty of the multidimensional CoV problem, we apply a novel technique introduced in [2]. Specifically, we use a Lyapunov function to map the multidimensional CoV problem to a one-dimensional problem, which allows us to bound the minimum cost to overflow by solutions of simple vector optimization problems. This technique is of freelance interest and will be helpful for analyzing different queue-length-based planning algorithms still.

In a recent work [5], the author shows that the "exponential rule" can maximize the decay rate of the queue-overflow probability over all scheduling policies. The ends up in this paper square measure comparable however completely different. The advantage of working with the algorithms instead of the exponential rule is that the algorithms are scale-invariant (i.e., the outcome of the scheduling decision does not change if all queue lengths square measure increased by a typical factor). Hence, we will use the quality sample-path large-deviation principle (LDP) rather than the refined LDP employed in [5] that's a lot of technically concerned. In addition, our results highlight the role that the exponent plays in determining the asymptotic decay rate. Finally, mistreatment the insight of our main result, we design a scheduling algorithm that is both close to optimal in terms of the asymptotic decay rate of the overflow probability and by trial and error shown to take care of tiny queue-overflow chances over queue-length ranges of sensible interest

IV. Proposed System

Our aim is to find algorithms for scheduling the transmissions such that the queues are stabilized at given offered loads. We are going to implement the throughput-optimal, to stabilize the transmission rate and reduce the load and finding which algorithm stabilize the entire system.

LINK planning is a crucial practicality in wireless networks thanks to each the shared nature of the wireless medium and also the variations of the wireless channel over time. In the past, it's been incontestable that by rigorously selecting the planning call supported the channel state and/or the demand of the users, the system performance will be substantially improved. Most studies of planning algorithms have targeted on optimizing the long average output of the users or, in different words, stability.

Our proposed scheme is two-fold. One half involves estimating the speed of high Overflows flows the opposite half involves shrewd the drop likelihood of receiving Flows. In this section, we tend to gift detail algorithms for these processes.

A. *Identification and Rate Estimation of High Flows*

In order to provide accurate fair sharing, Identification of high flows is required. To minimize the amount of flow states, we've to cut back the detection likelihood of little flows. In this paper,

we propose a generalized and increased version of this methodology of biased sampling that permits it to exponentially scale down the identification likelihood of a little flow. The system takes the advantage of the decay rate of the overflow likelihood.

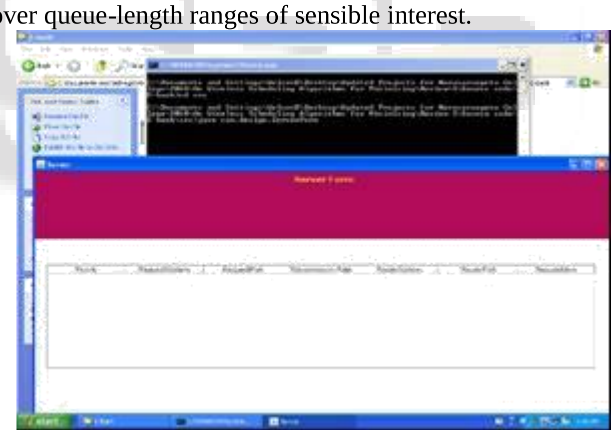
B. *Asymptotical Optimality of –Algorithms*

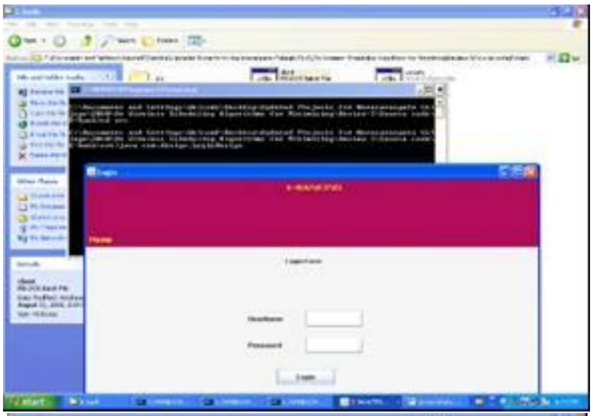
we will establish that within the limit as , the -algorithms asymptotically come through the biggest minimum price to overflow capable given in (11). To emphasize the dependence on , we use to denote the probability distribution conditioned on under the -algorithm (with particular value of).

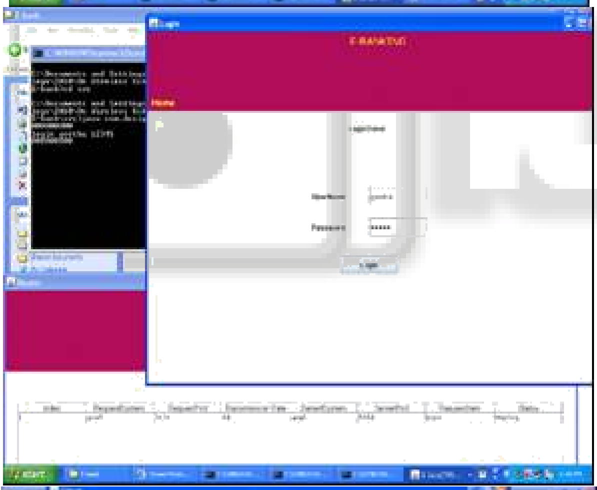
The proposed flow identification scheme maintains a cache consisting of n levels of k parallel registers containing k * n packets in total. After receiving a brand new packet, for each level of the cache, the scheme updates a randomly selected register with the new packet, with a certain probability. Consequently, we will assume that every level of the cache contains packets the whole range of that is proportional to the flow causation rates. With the projected cache, the projected theme identifies a high information measure flow as follows: once a flow is received, it is compared with the cache with a given probability, and the flow is known as a high information measure flow once every level of the cache contains a minimum of one be due it. Once a flow is detected as a high information measure flow, we create an entry for the flow in the hash table, and count flow from the flow in order to measure its sending rate. In the following analysis, we tend to show that the projected theme effectively reduces the identification likelihood for tiny flows[a].

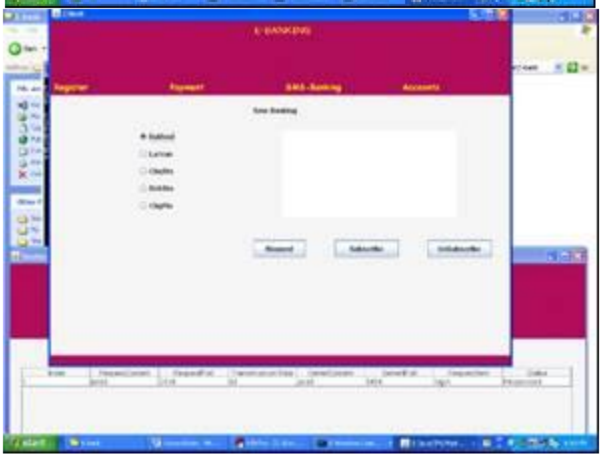
V. Result and Analysis

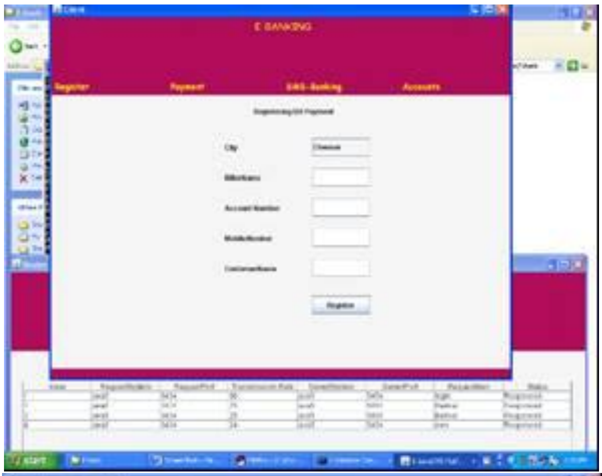
We proposed in wireless scheduling algorithms for the downlink of a single cell that can minimize the queue-overflow probability. Specifically, in a large-deviation setting, we are interested in algorithms that maximize the asymptotic decay rate of the queue-overflow probability, as the queue-overflow threshold approaches infinity. We 1st derive AN bound on the decay rate of the queue-overflow likelihood over all programming policies. We show that once the overflow metric is fitly changed, the minimum-cost-to-overflow beneath the -algorithm may be achieved by a straightforward linear path, and it may be written as the solution of a vector-optimization problem. Using this structural property, we then show that when approaches infinity, the -algorithms asymptotically achieve the largest decay rate of the queue-overflow probability. Finally, this result permits United States to style programming algorithms that are each near to best in terms of the straight line decay rate of the overflow likelihood and through empirical observation shown to maintain little queue-overflow chances over queue-length ranges of sensible interest.

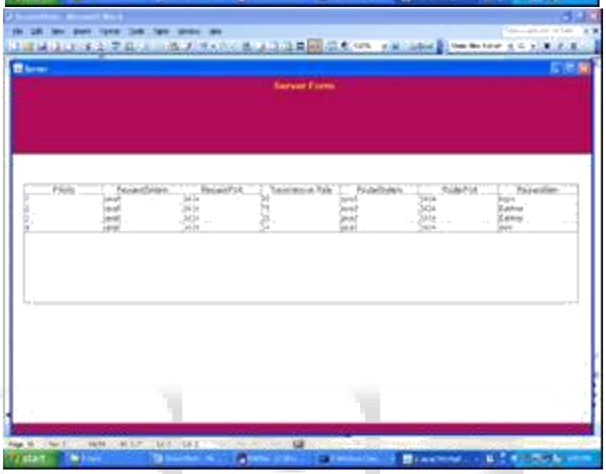












VI. CONCLUSION

This technique that is of freelance interest circumvents resolution the troublesome three-dimensional calculus of variations drawback typical during this kind of drawback. Finally, mistreatment the insight from this result, we tend to style hybrid programming algorithms that are each about to best in terms of the straight line decay rate of the overflow chance and empirically shown to keep up tiny queue overflow chances over queue-length ranges of sensible interest. For future work, we tend to attempt to extend the results to additional general network and channel models.

REFERENCES

[1] D. Shah, D. Wischik,"Optimal scheduling algorithms for inputqueued switches", in Proc. IEEE INFOCOM, Barcelona, Spain, 2006.

[2] S. P. Meyn, "Stability and asymptotic optimality of generalized Max Weight policies", SIAM J. Control Optim., Vol. 47, No. 6, pp. 3259–3294, 2009.

[3] M. J. Neely,"Order optimal delay for opportunistic scheduling in multi-user wireless uplinks and downlinks", IEEE/ACM Trans. Netw., Vol. 16, No. 5, pp. 1188–1199, 2008.

[4] M. J. Neely,"Delay analysis for maximal scheduling in wireless networks with bursty traffic", in Proc. IEEE INFOCOM, Phoenix, AZ, 2008, pp. 6–10.

[5] Shwartz, A.Weiss,"Large Deviations for Performance Analysis: Queues, Communications, and Computing", London, U.K.: Chapman& Hall, 1995.

