User-Level Performance of Channel-Aware Scheduling Algorithms for Wireless Data Networks

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Paper Code: MW-1

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Introduction

- Next-generation wireless networks will support many different types of data services, unlike current networks which are mainly geared toward supporting audio (telephone) services.
- The scheduling algorithm should depend not only on how many users there are, but also on what kinds of services they require.

Background Material

- Definition: Channel-Aware: “A protocol is defined as channel-aware if its algorithm recognizes and acts differently upon reception of events flowing on different channels.” [Miranda and Pinto: “Appia, a flexible protocol...”]
- In the past, channel-aware scheduling has mainly been concerned with cases that have a static user population.
- This paper looks at a dynamic user population, and investigates the effect of this change.

Principal Contributions

- User-level performance can be evaluated by a multi-class Processor-Sharing model where the total service rate varies with the number of users
- This paper presents exact results for the distribution of active users among the different classes, and their mean response times, blocking probabilities, and mean throughput.

Analytical Models

- The author of this paper developed several different analytical models to try to estimate the throughput and performance of different user configurations.
- To test how well these models worked, one set of experiments was performed.

Experiment Setup

- These were numerical experiments (simulations), not actual real-world tests
- Users initiate file transfer requests as a Poisson process
- At most 20 users in system simultaneously, any more than that are blocked and lost
- Uses a time-slot setup, with 600 slots per second

Experiment Setup, Continued

Nine different cases were created by pairwise combinations of SNR (Signal-Noise Ratio) and transmission rate variances:

- SNR Distributions:
  - I – identical to 0 dB for all users
  - II – bi-modal distribution, equal probability of either -2.0dB or 4.0dB
  - III – linearized normal distribution of SNR
- Transmission Rates
  - A – linear with SNR $R=C_1$ x SNR, C_1 = 400Kbs
  - B – log. in SNR $R=C_2$ x log(1+SNR), C_2 = 800Kbs
  - C – rate from Table 1

First Experiment

- Purpose was to determine the performance of a strategy they call ***S*. This strategy assigns a weight $w_i = 1/C_i$ to a user i with average transmission rate of C_i.***
- ***Simulations were run for 100M timeslots, or 167K seconds of real time.***
- ***Mean file size is 60KB***

Experiment Results

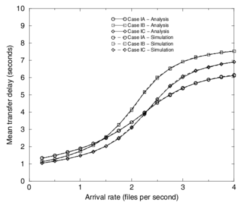

Fig. 2. Mean transfer delay as function of file arrival rate for Cases IA-C

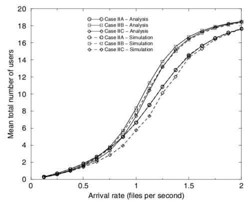

Fig. 3. Mean total number of active users as function of file arrival rate for Cases IIA-C

Where rate fluctuations are statistically identical, analytical formulas are highly accurate.

Results, Continued

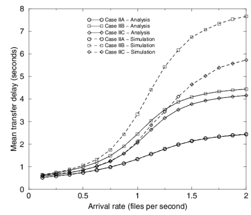

Fig. 4. Mean transfer delay for class-1 users as function of file arrival rate for Cases IIA-C

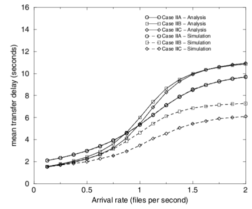

Fig. 5. Mean transfer delay for class-2 users as function of file arrival rate for cases IIA-C

Analytical Formulas understimate delay for high-SNR users (Fig 4) and overestimate delay for low-SNR users (Fig 5)

Results #3

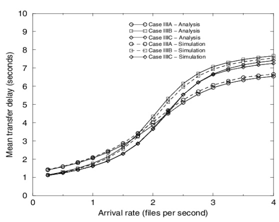

Fig. 6. Mean transfer delay as function of file arrival rate for Cases IIIA-C with deterministic file size

For cases IIIA-C, analytical formulas are again highly accurate.

Results #4

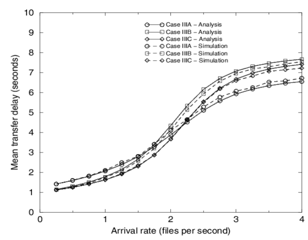

Fig. 7. Mean transfer delay as function of file arrival rate for Cases IIIA-C with exponentially distributed file sizes

Mean Transfer Delay is insensitive to file size distribution

Second Experiment

- In the second set of experiments, the purpose was to evaluate how different weighting schemes affects the performance of the system.
- These experiments used two user classes, with different weights assigned to each.
- Mean SNR values and weights of users are class-dependent. Within classes these values are identical.
- File size is same as before – 60KB.

Experiment 2 Results

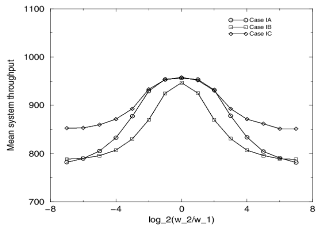

Fig. 8. Mean system throughput as function of $\log_2(w_1/w_2)$ for Cases IA-C

Best throughput when weights are identical. Differentiation between user classes can only be done at the expense of performance.

More Results

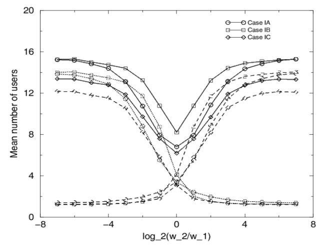

Fig. 9. Mean total number of users (solid line), class-1 users (dashed line), and class-2 users (dotted line) as function of $\log_2(w_1/w_2)$ for cases IA-C

Number of users best when weights are equal

Still More Results

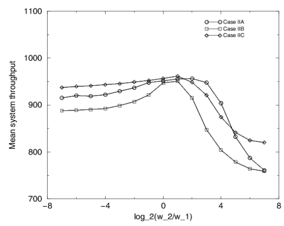

Fig. 10. Mean system throughput as function of $\log_2(w_1/w_2)$ for Cases IIA-C

Little performance impact if high-SNR users are given priority.
Great performance impact if low-SNR users are given priority.

Yet More Results

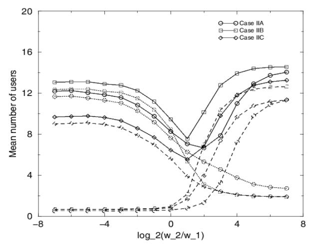

Fig. 11. Mean total number of users (solid line), class-1 users (dashed line), and class-2 users (dotted line) as function of $\log_2(w_1/w_2)$ for cases IIA-C

Most users can be served when priority of high-SNR users is only slightly greater.

Strengths of the Paper

- Provides very convincing evidence that considering a dynamic user population can affect performance.
- Backs up ideas with plenty of mathematical proofs and good simulation results.
- Presents both an analytical model and compares that model with results from simulations.

Weaknesses of the Paper

- Assumes an in-depth background of subject area.
- Provides no definitions of any terms used.
- Half of the paper consists of equations and proofs with very little discussion.
- Did not even explain the y-axis of Fig. 1.

Final Thoughts

- This was an extremely complex paper. It seems to me that the work done in this paper will help to improve the state of the art in wireless networking.
- More work needs to be done to see how practical these ideas are, and it is not clear how well these numerical simulations will reflect the real world, especially when determining the service class of different users, when they may be moving in and out of range of the base stations.

Questions

- What is the signal-noise ratio?
- Why is it important to consider a dynamic user population?
- What is the purpose of different user classes?
- What does it mean to be channel-aware?
- What type of wireless network does this paper focus on?