Service Rate Determination for Group of Users with Random Connectivity Sharing A Single Wireless Link

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May 31, 2007

Objective and Motivation

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Two-User Case

Extension to L Users

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- Obtain the long run server sharing policy that achieve the required QoS per each class of users.
- Provide a closed form formulation that facilitates a clear understanding of the system behavior in such environment.
- Study some of the popular scheduling regimes (e.g., Fair Scheduler and Equal Shares Scheduler) using the devised model and the obtained closed form formulation.

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- This method could be used as a guideline as well as a benchmarking tool for the dynamic scheduling policies especially when service differentiation is required.
- It also can be used to extend any existing policy to enable it to handle different QoS levels.

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- Study the effect of channel connectivity and service differentiation parameters on the server allocation.

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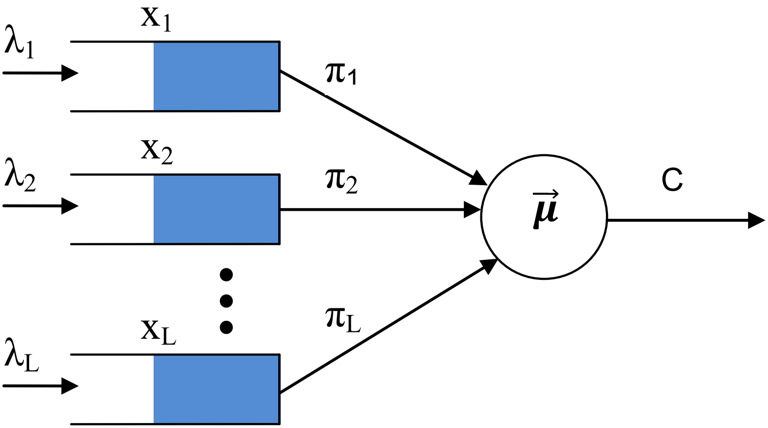
- Each queue is *connected* $(\pi_i = 1)$ with probability q_i: $i \in \mathbb{I}$, where $\mathbb{I} = \{1, 2, \ldots, L\}$ is the set of all queues in the system, and *not-connected* $(\pi_i = 0)$ with probability $1 - q_i$.

A Model For L Users Sharing One Wireless Link



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- The service rate received by queue i at any given time depends on the connectivity vector.

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We define the following parameters to be used in the proposed model

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- $m_i \in [0, 1]$ the average share of the server assigned to queue i.

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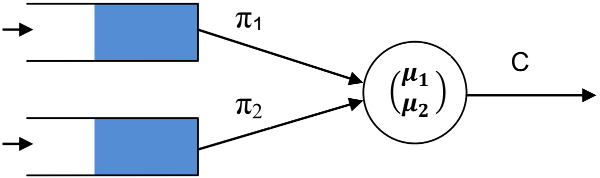
- The system is modelled by two queues sharing one server:



Service Rate Determination

- **Service Rate for Queue1:**

$$\begin{aligned} \mu_1 &= Cq_1(1-q_2) + Cm_1q_1q_2 \qquad \text{packets per second} \\ &= C(q_1 - q_1q_2 + m_1q_1q_2) \end{aligned} \tag{1}$$

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- **Service Rate for Queue2:**

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- The second equation required is; since it is not possible to assign more that 100% of the server capacity.

$$m_1 + m_2 = 1 \qquad where \quad 0 \le m_i \le 1 \quad (4)$$

Server Shares (m_1 and m_2) cont.

- Solving (3) and (4) for m_1 and m_2 yields

$$m_1 = \frac{1}{1+\nu}\left(1 - \frac{q_1 - \nu q_2}{q_1 q_2}\right), \quad 0 \leq m_1 \leq 1 \tag{5}$$

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- Substituting m_1 and m_2 in (1) and (2) above we get

$$\mu_1 = \frac{C\nu}{1+\nu}(q_1 + q_2 - q_1 q_2) \tag{7}$$

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- Assign all the resources to the connected user when there is one connected user, and divide the resources between the two users according to (5) and (6) when both users are connected.

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- Then (7) and (8) will be reduced to

$$\mu_1 = \mu_2 = \frac{C}{2}(q_1 + q_2 - q_1 q_2) \tag{11}$$

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- It can also be used as a benchmarking tool to evaluate the fairness level of already in use scheduling policies.

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- The average service rates in this case is:

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- This policy is fair only if $q_1 = q_2$.

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- $\mathcal{M}^{(n,i)} \subseteq \mathbb{I}$ is a subset of $\mathbb{I}$ that contains the element $\{i\}$ plus n other elements of $\mathbb{I}$.

Average Service Rate For User i

$$
\begin{aligned}
\mu_i \; = C \Bigg[& q_i \cdot \prod_{l \in \mathbb{I} \setminus \{i\}} (1 - q_l) + \sum_{\forall \mathcal{M}^{(1,i)} \subset \mathbb{I}} \left(\frac{m_i}{\sum\limits_{j \in \mathcal{M}^{(1,i)}} m_j} \prod_{k \in \mathcal{M}^{(1,i)}} q_k \prod_{l \in \mathbb{I} \setminus \mathcal{M}^{(1,i)}} (1 - q_l) \right) \\
& + \sum_{\forall \mathcal{M}^{(2,i)} \subset \mathbb{I}} \left(\frac{m_i}{\sum\limits_{j \in \mathcal{M}^{(2,i)}} m_j} \prod_{k \in \mathcal{M}^{(2,i)}} q_k \prod_{l \in \mathbb{I} \setminus \mathcal{M}^{(2,i)}} (1 - q_l) \right) \\
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& + \ldots + \frac{m_i}{\sum\limits_{j \in \mathbb{I}} m_j} \prod_{k \in \mathbb{I}} q_k \Bigg], \qquad \forall i \in \mathbb{I},\; n < L - 1 \qquad (14)
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- Equating μ_1 and μ_j for each $j \in \mathbb{I}\backslash\{1\}$ will result in $L-1$ equations with L unknowns.
- The L^{th} equation needed to solve this system of equations for $m_1, m_2, \ldots, m_L$ is

$$\sum_{i=1}^{L} m_i = 1 \quad \text{for all} \quad 0 \leq m_i \leq 1 \qquad (15)$$

Three Users Example

- When $L = 3$, equation (14) will be reduced to

$$\mu_i = C\Bigg[q_i \prod_{l\in I\setminus\{i\}} (1 - q_l) + \sum_{\forall \mathcal{M}^{(1,i)}\subset I} \left(\frac{m_i}{\sum_{j\in\mathcal{M}^{(1,i)}} m_j} \prod_{k\in\mathcal{M}^{(1,i)}} q_k \prod_{l\in I\setminus\mathcal{M}^{(1,i)}} (1 - q_l) \right) + \frac{m_i}{\sum_{j\in I} m_j} \prod_{k\in I} q_k \Bigg] \quad (16)$$

Three Users Example cont.

- The service rate for user 1 (μ_1) is given by

$$\mu_1 = C\Big[q_1(1-q_2)(1-q_3) + \frac{m_1}{m_1+m_2}q_1q_2(1-q_3) + \frac{m_1}{m_1+m_3}q_1q_3(1-q_2) + \frac{m_1}{m_1+m_2+m_3}q_1q_2q_3\Big] \quad (17)$$

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- The third equation required to solve the system of equations is

$$m_1 + m_2 + m_3 = 1$$

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- Study the allocation policy by finding μ_i and m_i under different working scenarios.

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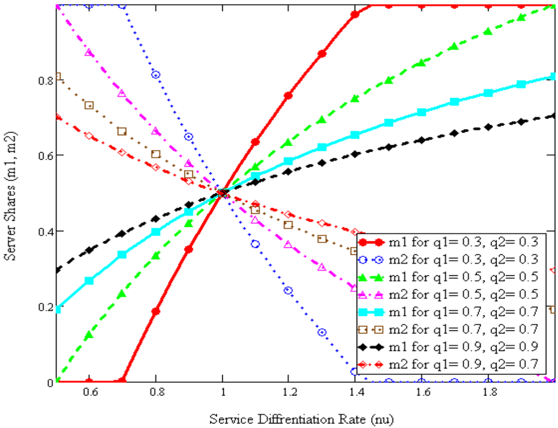
Service Share (m_i) vs. Service Differentiation Rate (ν)



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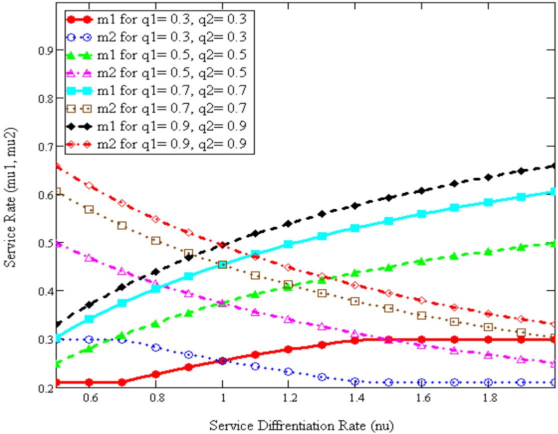
Average Service Rate (μ_i) vs. Service Differentiation Rate (ν)



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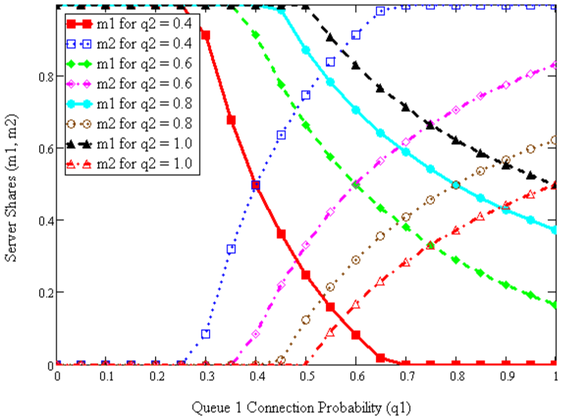

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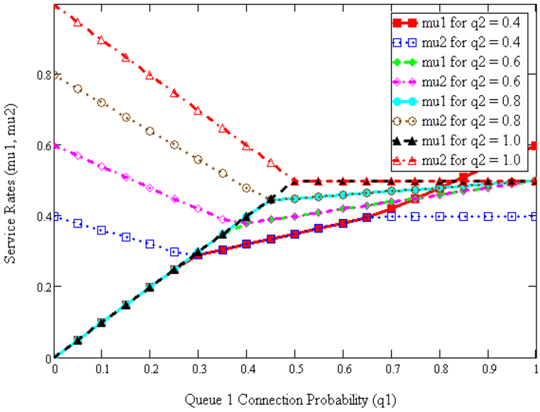

Case 3: Equal Shares Scheduler ($m_1 = m_2 = 0.5$)

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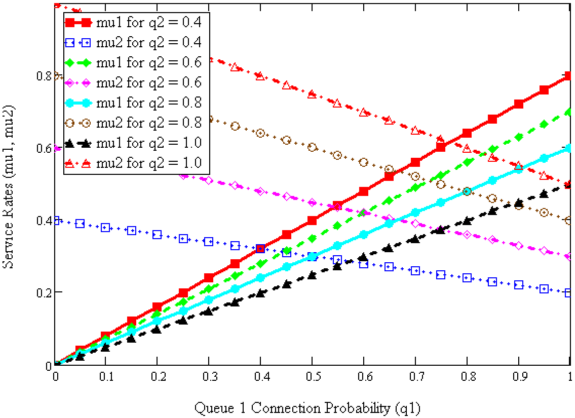

Case 4: Differentiated Services; $\nu = 2.0$

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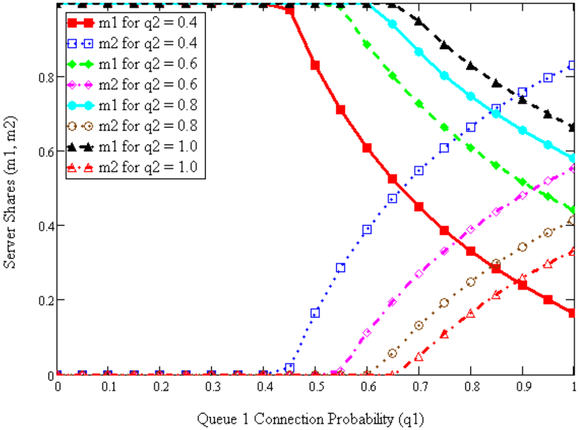

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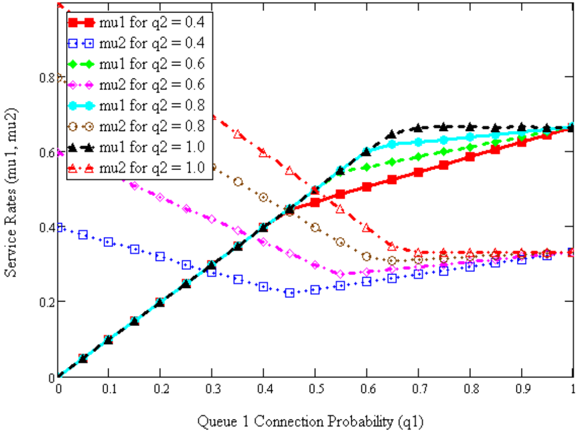

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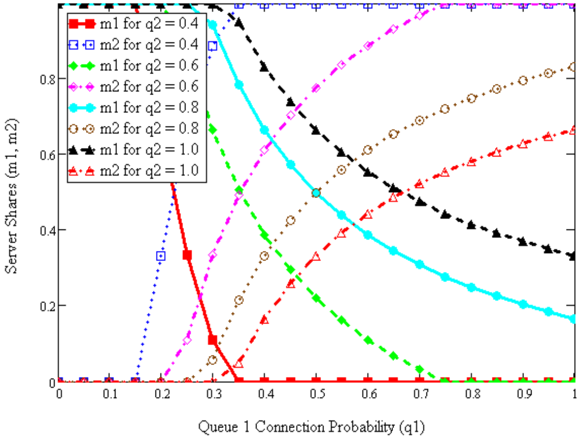
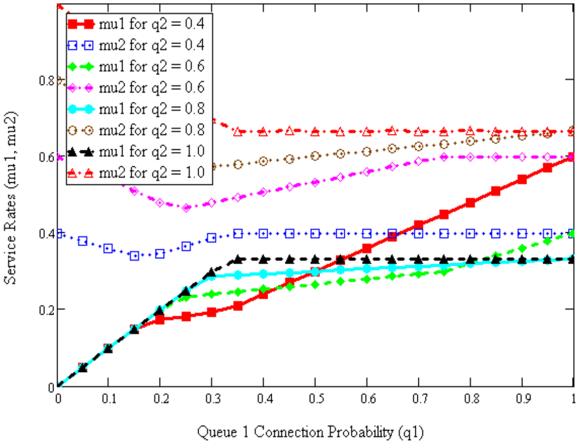


Case 4: Differentiated Services; $\nu = 0.5$

Average Service Rate (μ_i) vs. User1 Connection Probability (q_1)



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- Solving the model require much less computational complexity than the dynamic counter parts.
- The results proved that assigning equal shares of the server capacity to all users in a wireless system with independent random channel connectivity resulted in service differentiation that is highly dependent on the relative channel quality.
- It is also shown that fairness can only be achieved within a limited range of the channels' parameters. This range can be quantified using the proposed approach.

Future Work

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- The two-state channel model can be extended to a Finite State Markov Channel model. This will introduce more complexity to the model. Nevertheless, this will be a very interesting case to study, since most of the concurrent wireless systems use rate adaptation (i.e., adapting the rate to the channel conditions).
- The results can be used to study the long run fairness of some existent schedulers in wireless environment.

Thank You

Discussion

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