Class-based Bandwidth Management in Heterogeneous Wireless Networks

Ilias Tsompanidis [1], Ahmed Zahran [2], Cormac Sreenan [1]

[1] Department of Computer Science, University College Cork, Ireland
{it1,cjs}@cs.ucc.ie

[2] Electronics and Electrical Communications Dept., Cairo University, Egypt
azahran@eece.cu.edu.eg

Abstract

This work considers the network selection and the bandwidth assignment problems in the context of heterogeneous wireless networks operated by a single wireless service provider, assuming multiple client classes and the need for transparent operation from the users point of view. We present a centralised multiple-cell bandwidth management framework based on priority classes, that also serves as a robust centralised network selection algorithm. The novelty of this design is the use of priority classes with the simultaneous, utility-based optimisation of network selection and resource allocation for clients of different classes, while adhering to a "controlled unfairness" scheme, that allows for flexible bandwidth assignment. This poster presents a short report on this work-in-progress, along with a preliminary performance evaluation.

Keywords: Utility-based Centralised Resource Management, Priority Class, Heterogeneous Wireless Network, Bandwidth Management.

1 Introduction

With the deployment of 4G in parallel to 3G services wireless service providers (WSPs) find themselves operating different, but spatially overlapping technologies and networks. At the same time, customers use more powerful mobile devices and demand better service, with reliable, high-speed connections, every day. However, the amount of wireless traffic is urging WSPs to take unilaterally decided measures, such as the abolition of unlimited data allowance service plans and traffic throttling, discomforting customers. It is becoming obvious that a mutually beneficial bandwidth management scheme is needed. This work addresses the problems of network selection and bandwidth allocation, while investigating the idea of *controlled unfairness* in bandwidth management, by employing utility functions for clients belonging in different priority classes. The bandwidth sharing mechanism when demand is more than the available capacity is a basic component of this work.

Network selection and bandwidth allocation are popular topics among researchers. Centralised algorithms include the work by [Jia et al., 2006], presenting a bits/Hz ratio minimisation problem, effectively optimising spectrum allocation. That solution is in many parts similar to this work, though it does not accommodate for oversubscription, blocking a user when the requested bit rate is not available.

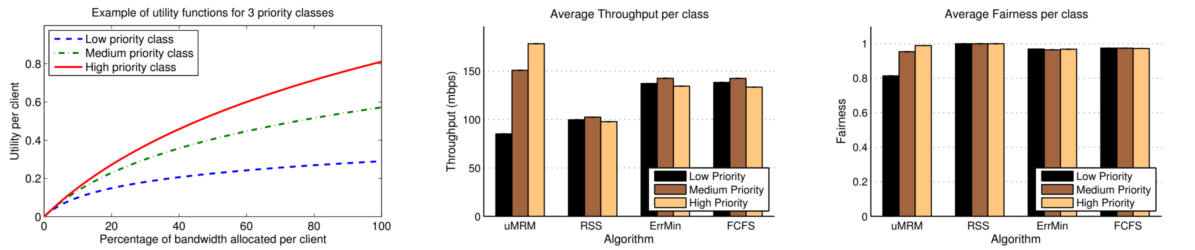
SUTIL [Pirmez et al., 2010] is a distributed network selection solution, based on utility function of bandwidth, packet loss, delay, and energy information using integer linear programming. The unrealistic assumptions of prior knowledge of the parameter requirements for every service used in the network, and network capacity sufficient for demanded traffic make SUTIL unattractive.

2 Our Approach

Bandwidth allocation and network selection are performed by maximising the total utility.

$$\max U = \sum_{i=1}^{n} f_{P_c}(B_c) \tag{1}$$

Utility functions f are defined as an expression of points of importance for units of allocated bandwidth B to a client c. Each client belongs to a priority class P, and each priority class is assigned a specific network-wide utility function f_P (Fig. 1a). The optimisation problem is bounded by a number of parameters which define a *snapshot* of the network, such as the Base Station (BS) capacity, the lower and upper throughput limits a network imposes on each priority class, and short-term estimations of the throughput the clients are able to achieve from the available BSs and their traffic demands. The properties of the utility functions define the dynamics of bandwidth sharing between clients in different priority classes.



(a) Utility functions for 3 priority classes with risk-averse behaviour [Arrow, 1976].

(b) Average throughput per class over 100 network snapshots.

(c) Average fairness per class over 100 network snapshots.

Figure 1: A preliminary display of the effectiveness of utility-based resource management (uMRM). Figure 1a presents the utility functions used. Figures 1b and 1c present the average throughput and fairness for a simple heterogeneous wireless network with 3 BS of different capacity simulated in MATLAB. The other network selection algorithms are a RSS-equivalent (RSS), a minimisation of *error* = $|Available\ BS\ bandwidth - Estimated\ client\ demand|$ (ErrMin), and First Come First Served (FCFS) where clients connect to the BS with the most available bandwidth).

A number of assumptions are made that are dependent on the actual implementations and access technology used, *e.g.*, the end user devices and access network equipment accept configuration from the network operator-coordinator, the devices upload information to the network about current status, and that the access networks employ priority queues similar to 802.11e Differentiated Services that converge in the long run to a stable bandwidth allocation. Message exchange supported by 802.21 make most of these assumptions reasonable.

Acknowledgments

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