

Dynamic Pricing Control in Cellular Networks

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Abstract—In this paper we present dynamic pricing control for network quality of service (QoS) in cellular networks. Dynamic pricing policies allow the network service providers to charge a cost per time unit depending on the availability of network resources; hence it regulates the arrival rate of calls of service to the network. This implies that network service requirements such as availability, reliability, security, bandwidth, congestion, routing, stability, delays, etc are maintained at an optimum level. These are the parameters that define the network QoS both within the network and at the edge access points where customer services are offered, leading to significant improvement in the network management. We model demand for the network service as a function of the arrival rate, which in turn is a function of the service price. The aim of this paper is to report on the application of control theoretical scheme for admission control in a simulated cellular network for improved quality of service.

Index Terms—Cellular networks, controller, dynamic pricing, optimal price, quality of service (QoS)

I. INTRODUCTION

The demand for mobile services has been rising exponentially. However, the bandwidth and frequency spectrum to support these mobile services is critically limited. To address the competition for scarce resources, GSM service providers need new tools to help them efficiently and effectively optimize their networks [1]. Several methods have been suggested such as cell splitting and frequency re-use [2], dynamic channel allocation or alternative routing [3], and adaptive cell-sizing algorithm. All these methods often imply either an increase in system complexity or a significant degradation of the quality of service.

An alternative approach is to attempt to modify user demands to fit within the available network resources in the cell. Currently, most mobile service providers have implemented static pricing strategies by offering cheaper (or free) off-peak calls as a marketing incentive, in an attempt to utilize the spare capacity. However, a major drawback of the current tariffs is their lack of flexibility and inability to take account of the actual network load or the status of the network resources, by merely increasing the tariffs when the operator anticipates high demand.

In this context, we propose a solution based on real-time or dynamic pricing techniques where the price for network resources are adjusted according to the availability of the network resources, hence making better use of the available bandwidth, and providing the desired QoS to the user as well

as greater revenue to the service provider. It presents the user with a price they are willing to pay. It is intuitive that the trend of user demand can be modified by imposing higher rates during peak-traffic time periods and low rates when large network resources are available. Thus, this pricing scheme can be used as congestion control, call admission control and resource management.

Dynamic pricing strategies have been mainly used to control wired networks supporting Internet-based services [5], [6]. In this case techniques to derive the system optimal rates have been proposed, which charge user on the basis of the congestion they cause to the network. Dynamic pricing on cellular networks is an emerging research domain. In [7] a self-regulated system is proposed and the goal of the algorithm is to maximize both the revenue for service provider and the welfare of the users, that is, to choose the pricing function, which offers the best utilization of system capacity whilst keeping the call blocking probability at a preset level.

A new dynamic pricing scheme for cellular networks is proposed in [8]. Unlike [7], [8] and [13] introduces the notion of call admission control. This scheme also shows a clear distinction between new calls and handoffs. In [9] yet another approach to dynamic pricing in mobile networks is presented. The main goal of this research is to maximize the total revenue by finding an optimal pricing function.

Since the system requires that charged prices varies over time according to the network load, the aim of this paper is to generate price according to the network load and to control the dynamic pricing system since its an oscillatory system which can be very unstable if not controlled properly.

This paper is arranged as follows; section I provides an overview of dynamic pricing strategy and the road map of the paper. We present cellular system modeling in section II. In section III, the controller design of the dynamic pricing strategy is described. Section IV presents simulation test results and we conclude the paper in section V.

II. CELLULAR SYSTEM MODELLING

The network capacity (resources) is denoted by $c(k)$, whose unit is the maximum number of packets that can be transmitted over the link per unit time. The arrival rate of guaranteed and best effort services depends on price and follows Poisson distribution with mean arrival rate $\lambda(k)$ given by

controller (compensator) is also needed to compare the reference network utility and the current system output so that a price is set each time (t), depending on the error. The general system is with the controller is given by figure 3.

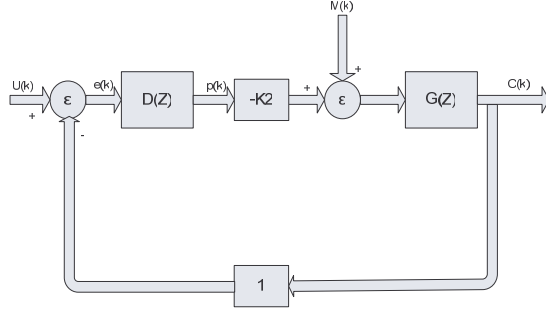


Figure: 3 Dynamic pricing system

where,

- $U(k)$ = reference network utility
- $e(k)$ = error
- $D(z)$ = controller
- $p(k)$ = dynamic price
- $M(k)$ = dynamic demand
- $G(z)$ = plant open loop transfer function.
- $C(k)$ = network resources

From figure 3, $M(k)$ input influences the plant output but is not controlled. Such inputs are called disturbances [11]. Usually the goal is to design the control system such that these disturbances have a minimal effect on the system. The dynamic pricing system output is given by

$$C(z) = \frac{-K_2 D(z) G(z)}{1 - K_2 D(z) G(z)} U(z) + \frac{G(z)}{1 - K_2 D(z) G(z)} M(z) \quad (10)$$

when $M(z) = 0$

$$C(z) = \frac{-K_2 D(z) G(z)}{1 - K_2 D(z) G(z)} U(z) \quad (11)$$

Hence in terms of frequency response, in order to reject the disturbance, we require that

$$K_2 D(e^{j\omega T}) G(e^{j\omega T}) \gg 1$$

over the desired system bandwidth. Then

$$C(e^{j\omega T}) \approx U(e^{j\omega T})$$

If we consider only the disturbance input, then

$$C(z) = \frac{G(z)}{1 - K_2 D(z) G(z)} M(z) \quad (12)$$

Hence, over the desired system bandwidth

$$C(e^{j\omega T}) \approx -\frac{G(e^{j\omega T}) M(e^{j\omega T})}{K_2 D(e^{j\omega T}) G(e^{j\omega T})} \quad (13)$$

Since the denominator of expression is large, the disturbance response will be small provided that the numerator is large.

Therefore the design of the controller $D(z)$ should be such that the right hand side of equation 13 is as small as possible. We designed a simple controller with different orders and the third order gave us the best results.

The compensator was found to have a transfer function of

$$D(z) = \frac{z - 0.7}{z^3 (z^2 + 2z + 1)} \quad (14)$$

IV. SIMULATION RESULTS AND TEST RESULTS

In this section, we show results obtained using our analytical model using MATLAB. We plotted the network blocking probability against the network load. Figure (4) shows that the two network parameters are directly proportional, that is, the higher the network load the higher the blocking probability.

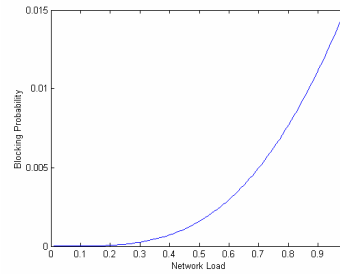


Fig. 4: Plot of Blocking Probability against Network Load

The normal arrival pattern of calls with a flat rate pricing strategy is given by figure (5). It can be observed that at time the network is under utilized and at times over utilized.

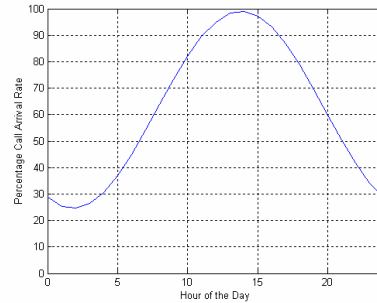


Fig. 5: Typical Daily Call Arrival Rate

We applied the blocking probability given by equation 2 to the daily call arrival pattern since the network resources cannot be operated at 100% usage, there must be some reservations. As figure 4, figures 6 and 7 indicate that the more the network resources are in use, the greater the blocking probability, until sometimes all best effort services are completely blocked.

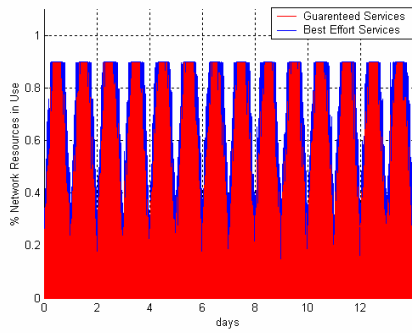


Figure: 6 Percentage Network Usage for both Guaranteed & Best Effort Services (two weeks)

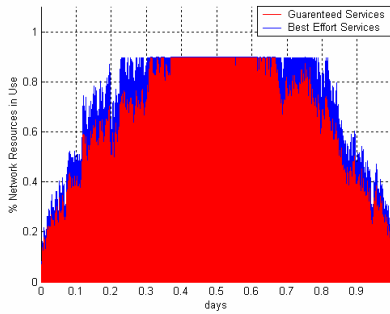


Figure: 7 Percentage Network Usage for both Guaranteed & Best Effort Services (one day)

We propose a dynamic pricing strategy to work with the network call admission techniques for call admission and hence resource management. When dynamic pricing scheme was applied to the network, the arrival of calls was controlled by the price being offered at any time t . Figure (8) shows that when price is high, only few people can willing to pay, hence network availability is high (which equivalent to low arrival rate), hence reduction in the number of users. In the other hand, if price is low, so many people can afford this hence high arrival rate (network resources become scarce), hence increase in the number of users. Whenever there is an imbalance in network resource price is used to maintain the resources availability at around 60%-70%.

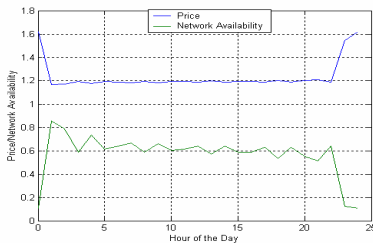


Figure: 8 Fractional network availability and dynamic price

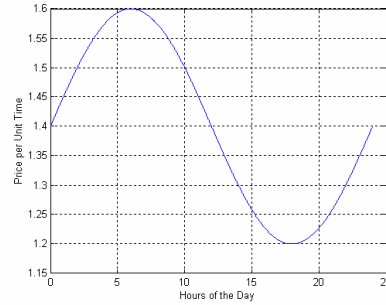
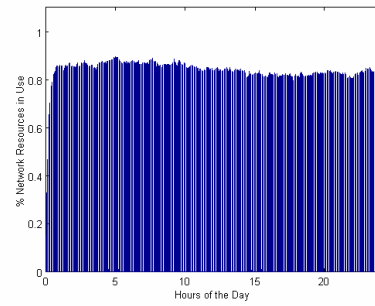


Figure: 9 Relationship between Sinusoid Price Function & Call in Progress

The two diagrams in figure 9 show that dynamic pricing can be used to maintain the network resource utility rate at around 80% to 90%.

To know the behavior of the system when the input is varied from zero to finite value, we plotted a closed loop step response of the system represented in figure (10).

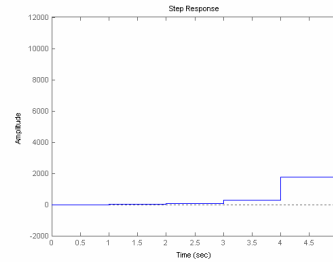


Figure: 10 Step response of the Controlled System

V. CONCLUSION AND FUTURE WORK

Dynamic pricing gives the user the freedom to use the network at a price they are willing to pay. Users are discouraged by high price during high network utilization and vice versa, resulting to reduction in congestion and hence high quality of service.

Future work includes extending the system to 3G and 4G systems. Since almost all the network characteristic information is contained in the mobile switching control (MSC), we recommend that dynamic pricing system be implemented here.

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