Dynamic Pricing in Wireless Networks

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Introduction

- Pricing strategies for an efficient management of wireless networks.
- Dynamic pricing techniques: prices are dynamically adapted to the network status.
- Pricing can affect user's behavior and allow for an efficient control of the network operational conditions.
- Better use of the available bandwidth and desired quality of service to the users as well as a greater revenue to the network operator.
- We propose a solution to dynamic pricing based on an analytical approach.

User demand model

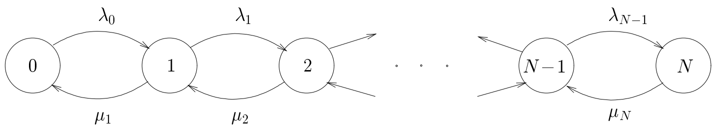
User demand function

$$D(p, Q) = \exp(-\alpha p + \beta Q)$$

represents the users active time expressed in seconds per time unit.

- p is the price per time unit
- $Q = 1 - P_b$ is the *quality of service* or *call success probability*
- P_b is the *call blocking probability*
- α, β are constant parameters related to the user population behavior

Birth-death Markov chain



- N is the maximum number of available communication channels.
- μ_i is the average call termination rate when the system is in state i $(1 \leq i \leq N)$.
- λ_i is the call arrival rate when the system is in state i $(0 \leq i \leq N-1)$.
- $(p_0, p_1, \ldots p_{N-1})$ is the *price vector* representing the cost per time unit of a call started when the system is in state i.

Call duration

Assuming that call durations are exponentially distributed with rates m_i $(0 \le i \le N-1)$ we have the average call duration of a call starting in state i

$$\frac{1}{m_i} = T_{max} \exp[-K_m(p_i - p_0)] \qquad 0 \le i \le N-1$$

- exponentially decreasing function of the call price per time unit in the range $[T_{min}, T_{max}]$ (e.g. $T_{max} = 180$s and $T_{min} = 60$s)
- $K_m = \ln(T_{max}/T_{min})/(p_{N-1} - p_0)$

Average call termination rate in state i

$$\mu_i = m_0 + m_1 + \cdots + m_{i-1} \qquad 1 \le i \le N \ .$$

Arrival rates

- The demand in the time span Δt is equal to the actual traffic that is generated in Δt, i.e., the traffic intensity γ weighted by the call success probability $1 - P_b$

$$\Delta t \exp[-\alpha p + \beta(1 - P_b)] = \Delta t \gamma (1 - P_b) \ .$$

- Since the traffic intensity in state i is $\gamma = \lambda_i / m_i$ we have the call arrival rate

$$\lambda_i = \frac{m_i}{1 - P_b} \exp[-\alpha p_i + \beta(1 - P_b)], \qquad 0 \le i \le N-1 \ .$$

Steady state solution of the Markov chain

$$\pi_0 = \left(\sum_{k=0}^{N} \prod_{j=1}^{k} \frac{\lambda_{j-1}}{\mu_j} \right)^{-1}$$

$$\pi_i = \pi_0 \prod_{j=1}^{i} \frac{\lambda_{j-1}}{\mu_j} \ .$$

- $P_b = \pi_N$ system blocking probability.
- Since λ_i and μ_i are also functions of P_b, the steady state solution must be computed iteratively until convergence on P_b is reached.

Network revenue and Average cost

- $(g_1, \ldots g_N)$ *revenue vector* representing the total revenue per time unit of the network operator when the system is in state i where

$$g_i = \sum_{j=0}^{i-1} p_j$$

- The total *network revenue per time unit* is

$$G = \sum_{i=1}^{N} \pi_i g_i$$

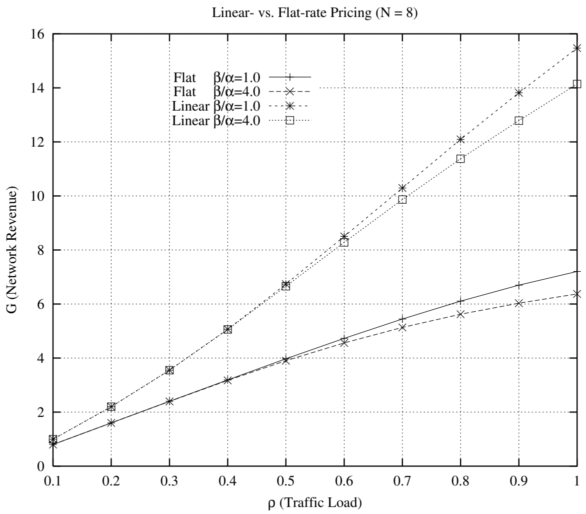
- Call *average cost per time unit*

$$\overline{c} = \sum_{i=0}^{N-1} \pi_i p_i \ .$$

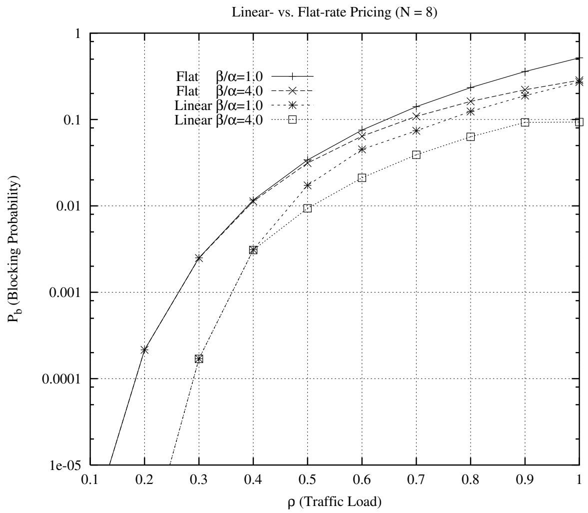
Pricing policies

- Evaluate a pricing policy (i.e., a price vector) maximizing the total network revenue G, while reducing the call blocking probability P_b.
- Optimization problem in its general form may be hard to solve numerically.
- Linearly increasing price vector which gradually discourages users from starting new calls as the network load increases.
- Baseline for comparisons we consider the *flat-rate* policy where the price vector is constant and the average call duration is fixed to T_{max}.

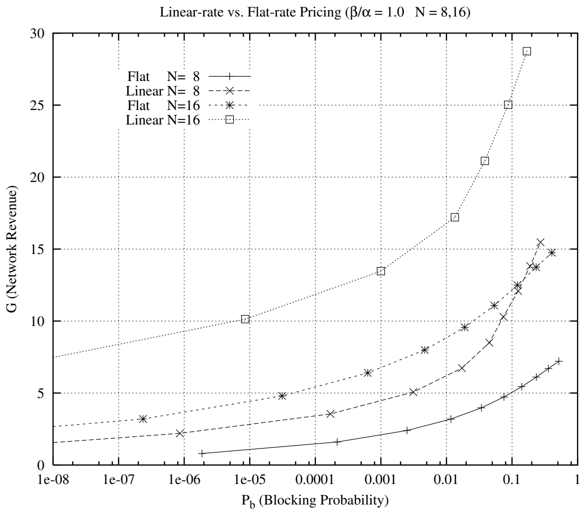
Linear vs. Flat-rate



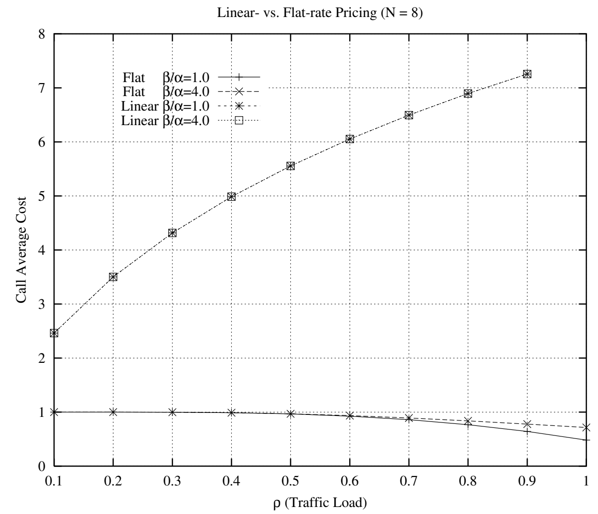
Linear vs. Flat-rate



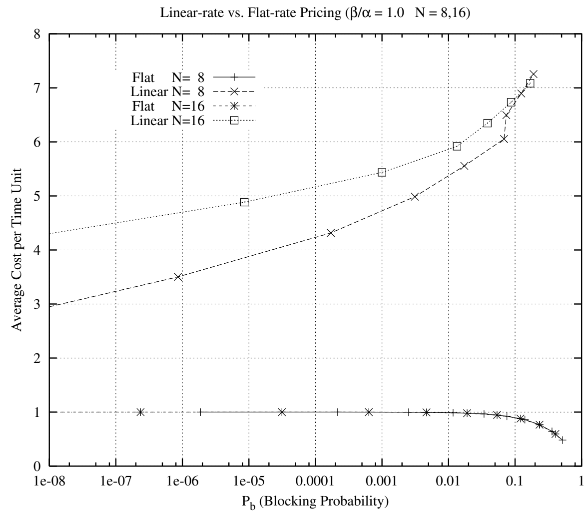
Linear vs. Flat-rate



Linear vs. Flat-rate



Linear vs. Flat-rate



Pricing for data packet services

- We consider different classes of users according to their desired information bit rate and actual bandwidth occupancy.
- Users require an information bit rate R_i; depending on the channel conditions and on their mobility profile the actual used bandwidth B_i may be greater than R_i due to the overhead of error correction functions.
- Multidimensional Markovian model to represent the system evolution.
- By solving the analytical model we can optimize the pricing strategies for the different user classes.

Conclusions

- The proposed method is an extremely flexible and simple tool to estimate the performance of dynamic pricing policies.
- More realistic parameters should be evaluated by the network operator according to their user population behavior analysis.
- The linear pricing strategy is not necessarily the optimal one. Further investigation is needed to solve the pricing problem to optimum.