Integration of WiMAX and WiFi:Optimal Pricing for Bandwidth Sharing

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Outline

- Introduction
- Pricing for Bandwidth Sharing
- System description
- Numerical results
- Conclusions

Introduction

- WiMAX has emerged as a promising technology for broadband access in wireless metropolitan area network (WMAN) environment.
- One of the potential applications of WiMAX is to provide backhaul support for mobile WiFi hotspots.

Introduction

- **INTEGRATION OF WIFI INTO WIMAX NETWORKS:**
  - Protocol adaptation
    - Layer 2 or Layer 3
  - Quality of service (QoS) provisioning
    - Per-flow or aggregate basis
  - Pricing for resource allocation in an integrated WiMAX/WiFi network

Introduction

- While the protocol adaptation and QoS issues mostly address the technical challenges in the integration of WiMAX and WiFi networks, the pricing issue relates to the control of radio resource usage from an economic point of view.

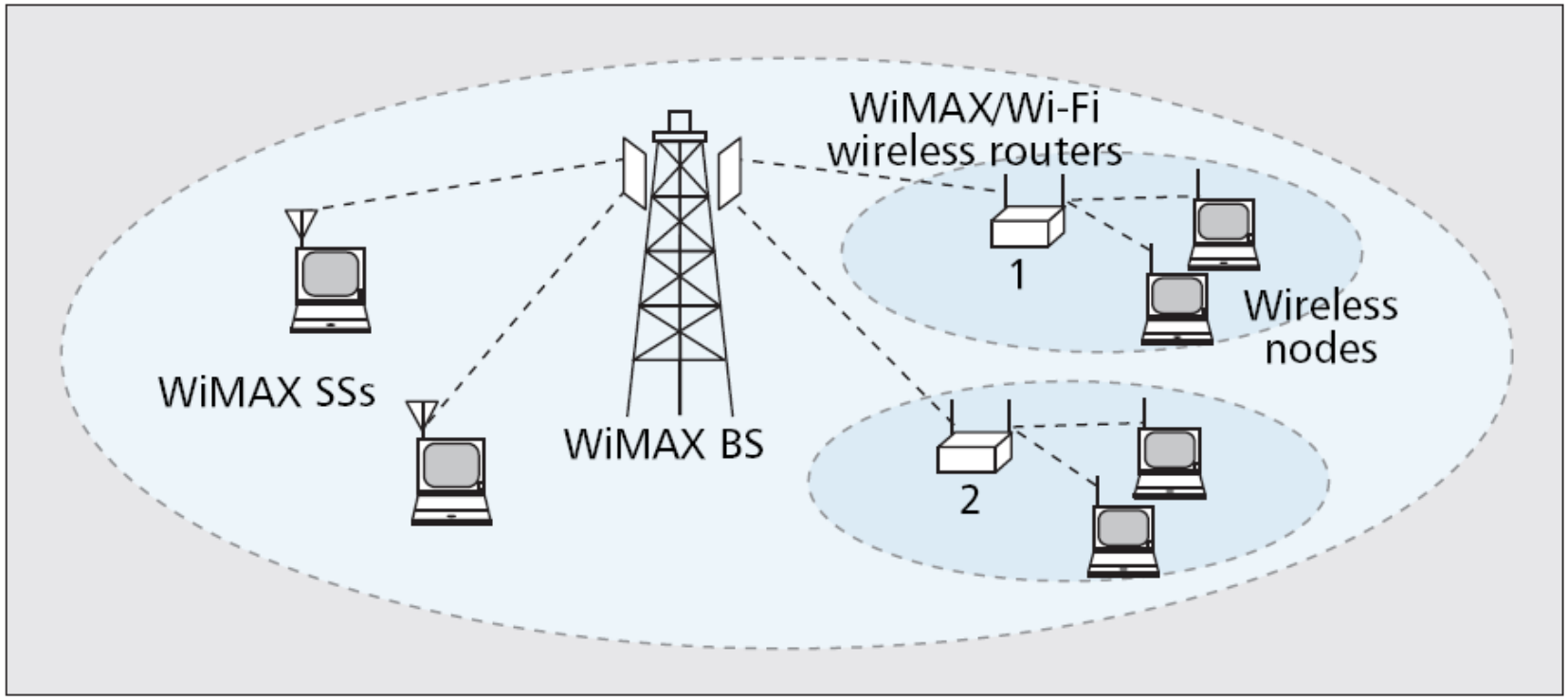

Figure 1. *An integrated WiMAX/WiFi network.*

The WiMAX BS and WiFi APs/routers are assumed to be operated by different service providers.

Pricing for Bandwidth Sharing

- Two major approaches to pricing are based on ***optimization formulation*** and ***game theory***.

Game-Theory-Based Pricing

- Nash equilibrium
- Max-min solution
- Stackelberg equilibrium
  - leader
  - follower

Stackelberg Game

- ***The players***
  - The WiMAX BS (i.e., leader) and WiFi APs/routers (i.e., followers) are the players of this game.
- ***The strategies***
  - For the WiMAX BS, the strategy is the price charged to the WiFi APs, and for a WiFi AP, the strategy is the required bandwidth.
- **The payoffs**
  - For both the WiMAX BS and WiFi APs/routers, the payoffs are the corresponding profits.

System description

- The WiMAX BSs and WiFi routers are operated by different service providers.
- The WiMAX BS charges the WiFi APs/routers for sharing the licensed WiMAX spectrum to provide mobile broadband Internet access to the WiFi clients.
- The WiMAX SSs have fixed bandwidth demand.
- The WiFi networks have elastic (i.e., time-varying) demand depending on the number of nodes and their preferences.

Revenue and Elastic Demand

- SSs serve real-time traffic,so the revenue of the WiMAX BS from SSs is a function of the correponding QoS performance.

$$R^{(s)} = \sum_{i=1}^{N_{ss}} \left[a_i - e_i D(\lambda_i, b_i^{(s)}) \right]$$

Revenue and Elastic Demand

- The WiFi networks serve best effort traffic,so the bandwidth demand by a WiFi node depends on the price charged by the WiFi AP/router.
- Based on the best response of the WiFi AP/router, the WiMAX BS can adjust the price charged to a WiFi AP/router to achieve the highest payoff.

GENETIC ALGORITHM AND LEARNING PROCESS

- A genetic algorithm is employed at the WiMAX BS and WiFi AP/router to gain knowledge of bandwidth demand and adjust the price.
- With backward induction beginning at the WiFi router, the game is solved.

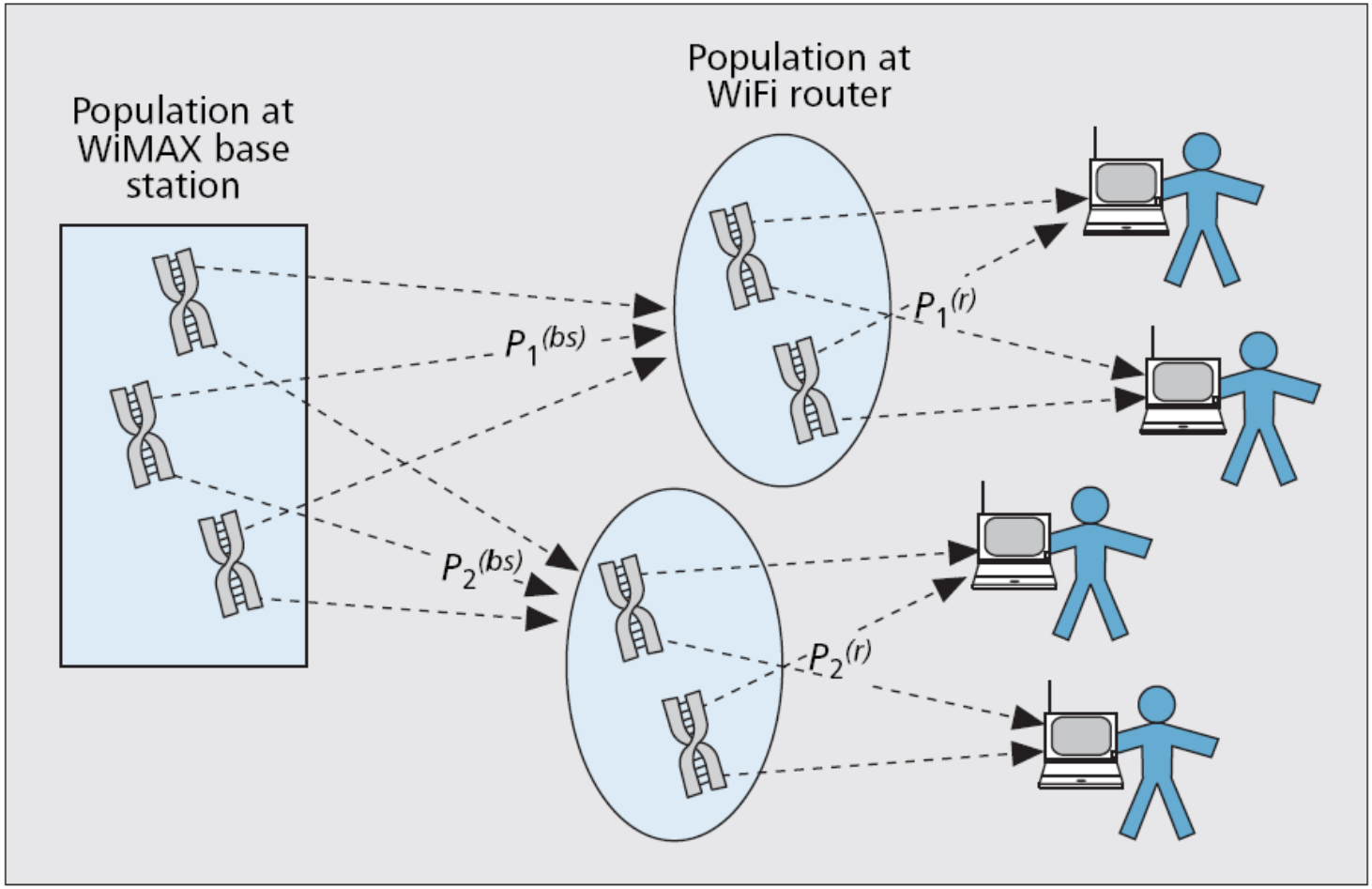

Figure 2. *Genetic algorithm for Stackelberg game for bandwidth sharing.*

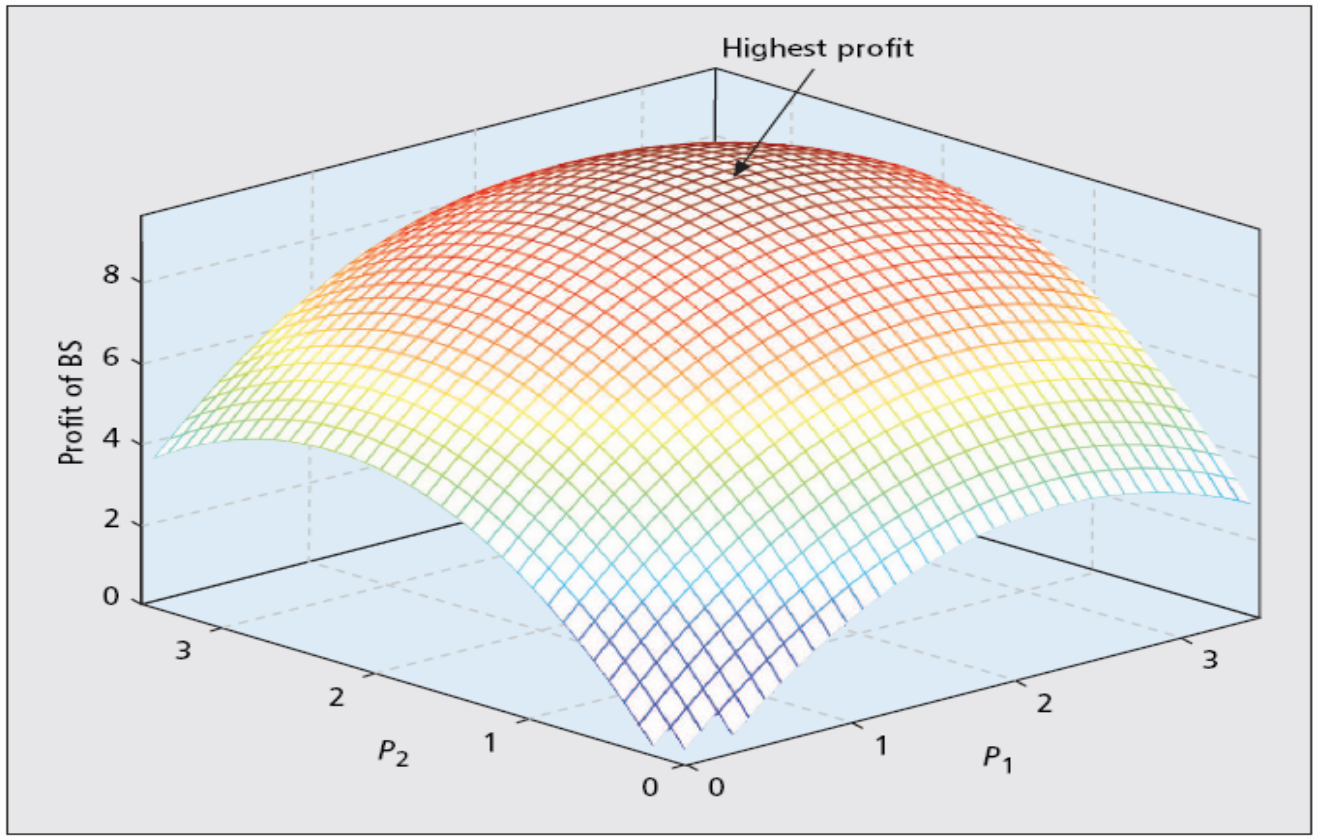

Figure 3. *Profit function of the WiMAX BS.*

Numerical results

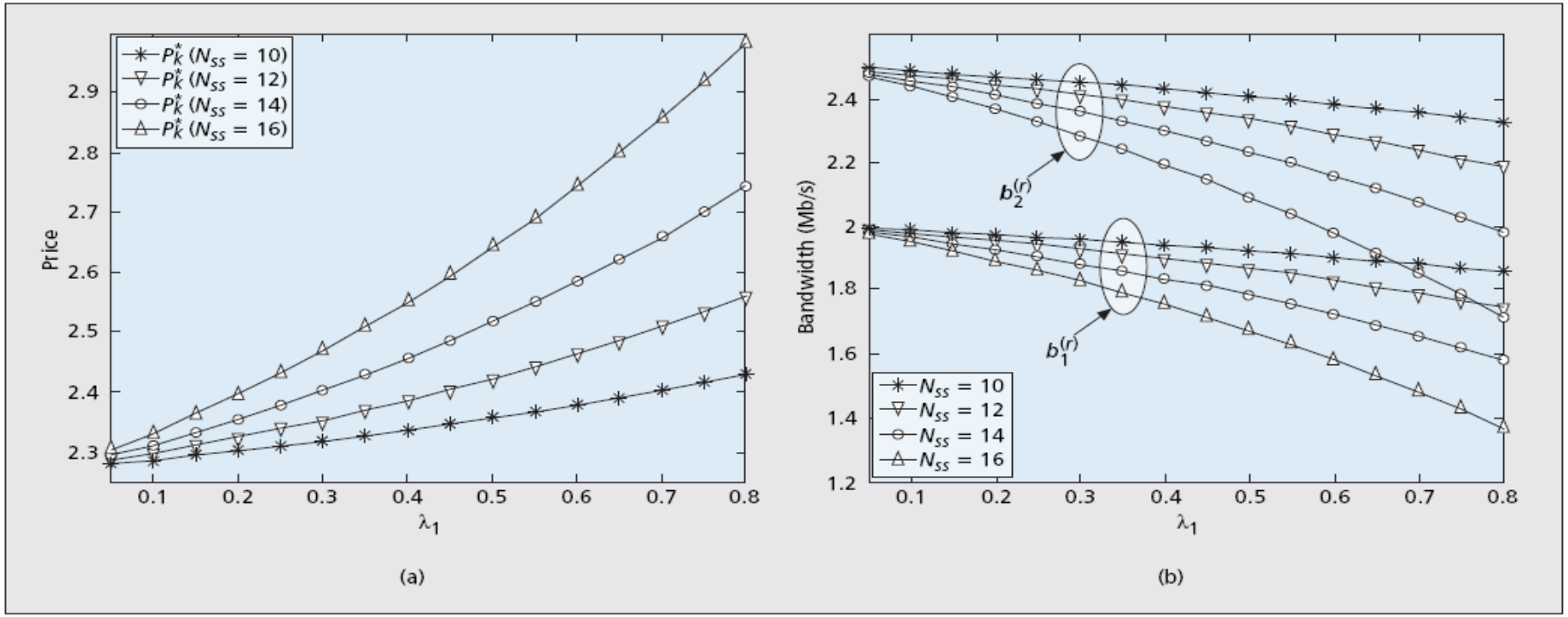

Figure 4. *a) Price and b) bandwidth sharing at the equilibrium under different traffic loads at the subscriber stations.*

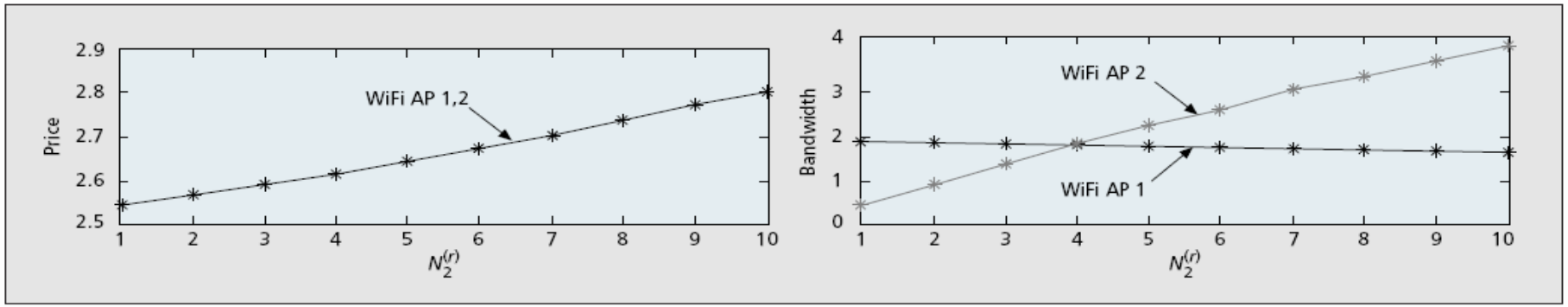

Figure 5. *Price and bandwidth sharing at the equilibrium under different numbers of WiFi nodes served by WiFi router two.*

Conclusions

- **Game theory** has been used to analyze and obtain the optimal pricing for bandwidth sharing between a WiMAX BS and WiFi APs/routers, taking into account the bandwidth demand of the WiFi users.
- A **genetic algorithm** has been used to iteratively obtain the solution of this game when complete bandwidth demand information is not available.

Conclusions

- This proposed bandwidth sharing and pricing scheme will be useful for both WiMAX and WiFi service providers to adopt efficient business strategies for integrated WiMAX&WiFi networks.