Waiting-Line Auction for WiFi Pricing

Tao Han, Liang Ma, Yuan’an Liu
Key Lab. of Universal Wireless Communications, Ministry of Education
Beijing University of Posts and Telecommunications
hantaobupt@gmail.com

ABSTRACT

We model the relationship between a WLAN access point (AP) and a paying client as a waiting-line auction [1] in which clients bids for transmission using the length of Contention Window (CW) as bid signals. The shorter CW is, the higher the access probability is, thus the higher pay to AP. The clients adapt their CWs based on the information acquired from current service load and wireless environment. Clients could achieve equilibrium bids according to Nash Equilibrium strategy.

1. INTRODUCTION

Currently, a large number of WiFi base station are deployed by private individuals and are encrypted to prevent outsiders from accessing them. To incentive owners of existing private wireless base stations to open their networks to public, as well as to incentive people and institutions to deploy WiFi stations to cover the coverage gaps and lead to a ubiquitous coverage, authors in [2] present game theoretic modeling of WiFi pricing toward web browse service, file transfer service and hybrid service.

In this paper, we model the relationship between WiFi owner as a wireless AP and the mobile station (MS) as waiting line auction. The AP performs as an auctioneer while MSs work as bidder. On the one hand, APs are willing to open their networks to public to gain money compensate. On the other hand, MSs intend to access to networks at an acceptable rate with minimal payment. APs charge MSs according to the rank of CWs: the MS which have a shortest CW in a given duration will pay most compensate since it would have highest access possibility and would cause other MSs delay. The MS uses its CW as bid signal, which is generally inversely proportional to actual bid. MSs adapt their bids based on two dimensional senses. The first dimension is the queue length of MAC layer that indicates current service load. When queue length exceeds a predefined valve value, the MS would shorten CW to increase the access possibility. While on the other hand, MS would enlarge CW. The other dimension is their access rate in a given time period which indicates the competitive level of wireless environment. This dimension determines the exact adaptive amount according to Nash Equilibrium strategy function of waiting-line auction.

2. AUCTION GAME MODEL

On the WiFi owners’ side, we assume network owner charges clients at the end of certain duration $T$. The AP utilizes hash chain by repeated evaluation of one-way hash function [3]. For simplicity, we assume the charging price $p_i$ is inversely proportional to CW: $p_i = \frac{k}{CW_i}$, where $k$ is a constant factor. It like clients in waiting line auction game would come earlier if they have a higher value of time. Then we derive AP’s utility function:

$$U_{ap} = \sum_i p_i x_i$$  (1)

where $x_i$ represents how many frames the user $i$ has transmitted in duration $T$.

On the MSs’ side, MS choose proper CW as bid signal. We assume MS’s valuation $v_i$ for transmission is related to it MAC queue length. MS would have a high valuation toward transmission when the queue exceed predefined valve, vice versa. We further assume there is an opportunity cost, $\gamma_i$ of MS to compete for access. Thus, the utility of MS $i$ can be express as:

$$U_{ms_i} = (v_i - p_i)x_i - \gamma_i$$  (2)

The MS’s optimal choice of $p_i$ depends on its transmission value and its competitors’ valuation of transmission. We assume each MS’s uncertainty about rivals’ valuation for communication is represented by the same probability distribution. In equilibrium, MS with higher value for the transmission would shorten its CW thus higher its bid price. The relationship, denoted by $\rho(v)$ with $\rho' > 0$ determines the equilibrium bid price for MS [1].

Proposition 1: the function $\rho(v)$ is Nash Equilibrium strategy function of waiting-line auction for WiFi pricing, and $p = \rho(v)$ is MS’s equilibrium bid.

1The proof is not provided here for saving space; it can be found in [1]
3. ACCESS PROTOCOL AND ALGORITHM

In the beginning of duration $T$, each MS would compute hash chain of a one-way function $H$ [3]. The hash chain contains values $x_0, x_1, x_2, ..., x_n$ where $x_1 = H(x_{i+1})$. Here, when the CW is chosen, MS will choose a random number in CW as its backoff time, and CW keeps constant in the duration $T$. Then, MS signs the cascade of $x_1$ and CW with its signature. In each subsequent time slot, the MS makes another payment by passing the next consecutive value of the hash chain to AP. At the end of $T$, AP charges MSs using function (1). To prevent MS false report its CW, AP also keeps the statistics of each MS’s access rate. If a MS which reports a larger CW has a higher access rate than a shorter one, AP believes the MS falsified its CW. As a result, AP will refuse to provide service to this MS.

MS adapts its bid according to its valuation for transmission that is characterized by queue length and load from upperlayer\(^2\). When its queue $Q_i$ exceeds a predetermined valve $V$, MS would shorten CW to prevent overflow under following constrains:

$$r_i \geq lo_i$$

where $r_i$ is its expected access rate and $lo_i$ is its load. On the other hand, when $Q_i$ below $V$, MS would be willing to enlarge CW to save money. However, it should keep a reasonable access rate which satisfies following inequations:

$$r_i \geq lo_i - \frac{V - Q_i}{T}$$

(4)

According to waiting-line auction, we assume if MS has a value of transmission as $v^*$, it will attain at least one transmit slot. We further assume $v_i = \beta r_i$, thus MS’s rate adapting can be expressed as follows:

$$p_i = \int_{\beta r_i}^{\beta r_i + V - Q_i} f(x)dx; \text{where } Q_i \geq V$$

(5)

$$p_i = \int_{\beta r_i}^{\beta r_i + V - Q_i} f(x)dx; \text{where } Q_i < V$$

(6)

Where $f(x)$ is the access density function when MS has a valuation of $x$. The distribution function can be expressed as:

$$F(x) = \frac{\sum_{v \leq x} \eta_A(v)}{\sum_{v \leq x} \eta_A(v) + \sum_{v \leq x} \eta_C(v)}$$

(7)

Where $\eta_A(v)$ and $\eta_C(v)$ represent access rates and collision rates of bids with valuation of $v$ respectively. We can derive $CW_i$ from above equations, $CW_i = \frac{k}{p_i}$.

4. SIMULATION RESULTS

\(^2\)We assume MS could predict the load here

The throughput curves of original WiFi and Waiting-Line Auction are illustrated in Figure 1. In the initial period, the performance of Waiting-Line Auction is poor because the node does not have enough information of the environment and the CW adjustment has not achieved a proper value. So after that, the performance of it is much better than that of original WiFi.

5. CONCLUSIONS

In this paper, we model WiFi Pricing scenarios as a waiting-line auction. MS adapts its bids that is characterized by CW according to Nash equilibrium strategy. AP charges MSs at the end of duration $T$. Through this model, the throughput of WiFi can be enhanced under certain conditions.

6. REFERENCES

