The Wi-Fi Roaming Game

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Abstract. We propose an extensive-form game as a model for pricing roaming charges in 802.11 wireless data networks. We specify utility functions for the three agents involved in the game: the wireless user and the visited and home operators. With realistic assumptions, we use the model to find optimal roaming prices for delay insensitive users.

1 Introduction

In wireless telecommunications, roaming refers to the provision of service in a location other than the home location of the service subscriber. The economic aspects of roaming in cellular voice networks have been studied in the literature [1,2,3]. In such networks, supporting roaming is a static decision which is enforced by a “roaming agreement” between the operators. However, new wireless networks with different properties, such as 802.11, are growing in ubiquity. In 802.11 wireless networks, user accounting and incentives of operators for providing roaming are different from cellular voice networks. In addition to geographical coverage, 802.11 network operators are interested in supporting roaming for better quality of service and load balancing. In these networks, the decision of whether to provide service to a roaming user or not should be made dynamically, especially considering that 802.11 is an open system [4] and users can easily switch between networks.

In this paper, we propose an extensive-form game as a model for users’ roaming between multiple 802.11 wireless data networks. We specify the utility functions of the agents involved in the game according to the network properties of the 802.11 protocol. We then examine a specific version of the game to find the behavior of the network operators when charging delay insensitive users for roaming.

In the next section we present the model and specify the utility functions. We will then outline a simplified version of the game in section 3 to gain insight into the properties of the game equilibrium. Finally, section 4 concludes the paper and presents some future work.

2 Modeling

Assume two operators, A and B, have installed infrastructure for wireless mesh networks in an urban area. In some areas their network coverage is exclusive
and in other parts, such as heavily crowded malls, their coverage overlaps. Two extensive-form games for roaming users can be envisioned:

1. **User initiated hand-off**: A subscriber to A proposes to connect to an access point belonging to B. B is called the *visited operator* and A is the *home operator*. The visited operator has two choices: *admit* or *reject*. If B decides to admit, the home operator may *agree* or *disagree* with the hand-off.

2. **Operator initiated hand-off**: As the home operator, A may instruct a subscriber to *switch* to the other operator. If the subscriber decides to switch, the visited operator may *admit* or *reject* the request. The open nature of 802.11 networks and the limited control of the operators over the users, make the *operator initiated* hand-off scenario impractical.

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**Fig. 1.** User-initiated roaming game

In this paper we will focus on the first scenario because the technical properties of the 802.11 standard [4] suggest that *user initiated* hand-off is more realistic. As demonstrated in Figure 1, the user initiated hand-off is a *perfect information extensive-form game* $G = (N, A, Z, u)$ where:

- The set of agents is $N = \{ \text{user, home, visited} \}$.
- The set of actions available to agents is $A = \{ A_{\text{user}}, A_{\text{home}}, A_{\text{visited}} \}$ where $A_{\text{user}} = \{ \text{switch, stay} \}$, $A_{\text{home}} = \{ \text{admit, reject} \}$ and $A_{\text{visited}} = \{ \text{agree, disagree} \}$.
- The set of terminal choice nodes is $Z = \{ X_1, X_2, X_3, Y \}$.
- The utility function, $u$, of each agent in each terminal node is defined in section 2.1.

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1 Mesh network deployments are not planned, therefore each operator may suffer from bad signal quality in some locations.
2 The home operator can enforce its decision, if it does not agree, by denying to pay the charges to the visited operator.