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Incentivizing the global wireless village ☆

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ABSTRACT

The wireless community networking paradigm shows great promise in achieving a global status. However, in creating a "global wireless village", both user participation and support from traditional Internet Service Providers (ISPs) are key ingredients; for this end a viable incentive system is essential. In this paper we investigate the economic interactions in global wireless community networks with regard to users, ISPs and community providers (called mediators) with both analysis and data-driven simulation. The main contribution of this paper is threefold. First, we develop a model of the global wireless community concept as a Stackelberg game of participation at two levels (the mediator as leader, and the users and ISPs as followers). Second, we analyze equilibrium properties of the game for users, ISPs and mediator. Our main finding is that the heterogeneity of user home location relevance is necessary for an economically feasible system. Third, we support our analytical claims with simulation results on the evolution of the user population. We show that the emergence of a truly global wireless community network is indeed possible.

1. Introduction

User-provided networking has seen its stock rising recently. While some see this concept as an interesting but only moderately viable alternative to the traditional Internet Service Provider (ISP)-centric paradigm, others believe it has the potential to induce a complete shift in Internet communication patterns. The latter view can be justified by four important disruptive aspects of user-provided networking. First, since the end-user can share or sell her own resources (e.g., connectivity), the distinction between end-user device and network device disappears. Second, the nature of wireless media, human mobility and the rise of micro-operators create the need for protocols that inherently handle intermittent connectivity, opportunistic relaying and smooth roaming. Third, user-provided services require traditional trust relationships to be transformed: social networks of trust should be formed to ensure the willingness to cooperate and to maintain network growth. And last, swift adoption of new technologies is possible as adopters are the end-users themselves. We strongly believe that these novel characteristics and features enable user-provided wireless networking to be the foundation of the future wireless Internet.

We refer to a wireless community network with worldwide coverage as the *global wireless village*. A working prototype of such a network already exists: the FON WiFi system [1]. Community members, referred to as Foneros, share their home Internet connections and gain access to free WiFi at other locations. The great interest of users in sharing their broadband connection over WiFi is reflected in the fact that there are more than 1 million FON access points all over the world. There are three different types of Foneros: Linus, Bill, and Alien. A Linus has a "La Fonera" WiFi router, shares his connection and gets free roaming at any FON Spot. A Bill, having the same rights as a Linus, gets further 50% of the revenues when a visitor purchases a FON pass at her FON Spot. An Alien does not have a "La Fonera" router and therefore does not share an Internet connection; she accesses FON Spots by purchasing FON passes. Since its inception in 2005, a number of prolific companies

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have partnered the FON movement: Google, Skype and British Telecom (BT) among others.

Since recent legislation efforts, e.g., in Germany [2], and ISP policy changes [3] require broadband users to secure their home wireless networks, the endorsement of ISPs for sharing home broadband is becoming essential. Furthermore, telecommunication law in certain countries, e.g., the United States, bans communities from providing their own community networks, therefore they have to go through a commercial ISP [4]. Unlike municipal wireless networks, which are mainly or partially operated by the local or national government, we focus on community networks, where users share their own (purchased from commercial ISPs) broadband connections over wireless. We argue that although FON and global wireless community networks (Whisher [5], WeFi [6] and local Meraki [7] among others) in general show great promise, their ultimate success depends on properly designed incentive mechanisms for both users and ISPs. The global wireless village should be as much user-provided as ISP-endorsed: a dual support is essential to achieve global wireless connectivity.

While the existing literature focuses either on local community networks or provider-based WiFi [11–14], our work aims at modeling a global wireless community, where ISPs also play an important role, and the presence of incentives and the proper dynamics of deployment are crucial. As evidenced by the growing number of ISPs partnering with FON (BT, Neuf, Time Warner, etc.), studying the economic interactions among users, ISPs and community providers is a key topic. Moreover, we argue that incorporating user mobility and home location relevance into our model brings us closer to the thorough understanding of the global wireless village. There has been a surge in research results in mobility measurements and models recently [10,21,22]. We use the findings of these papers and propose a mobility and location relevance framework.

In this paper we investigate the economic interactions in global wireless user-provided networks with regard to users, ISPs and community providers (called mediators) through game-theoretic analysis and simulation experiments driven by real-world data. Our main contribution is threefold. First, inspired by the FON concept, we build a game-theoretical model rooted in the Stackelberg game, incorporating user, ISP and mediator games as sub-games. We model the user participation decision both as single-shot and evolutionary games. Also, we consider homogeneous and heterogeneous payment distribution among members. At the ISP level, we propose a one-shot game of two players, which captures the essence of the ISPs' struggle whether to support the community access sharing. Also, the mediator acts as the leader, setting cost and revenue share parameters setting the pace. Second, we derive the Nash equilibrium points of the homogeneous and heterogeneous one-shot user games. Moreover, we show how the evolutionarily stable strategies of the homogeneous user game are among the equilibrium strategy profiles of the one-shot game. Our main finding is that the heterogeneity of user location relevance is necessary for an economically feasible system. Furthermore, we show how all ISPs either adopt or defect against the global wireless village in Nash equilibrium, depending on the parameter setting. Later, we demonstrate two possible design goals for the mediator (maximizing profit or social welfare) and show numerically how she can achieve them. Third, we define a sophisticated mobility graph incorporating the social aspects of human mobility and location-dependent user home relevance. Using this graph as playing field, we simulate an evolutionary user game with heterogeneous payments. We find that high-relevance users drive the technology diffusion. Moreover, the current penetration and structure of community networks, such as FON, enable them to expand towards global coverage, possibly creating the global wireless village.

The structure of this paper is as follows. We give a short overview on related work in Section 2. We go through the basic notions of game theory in Section 3. We develop a model of the global wireless community concept as a Stackelberg game of participation and construct the respective payoff functions of the mediator, ISPs and users in Section 4. We derive equilibrium properties of the proposed one-shot and evolutionary games, and study the optimal parameter settings of the mediator in Section 5. Next, we define the mobility model and the evolutionary game with heterogeneous payments, and present simulation results in Section 6. We outline possible future research directions in Section 7, and finally conclude the paper in Section 8.

2. Related work

Here we give a brief overview on related research efforts. We focus on two main topics: wireless community networks (WCN), and mobility measurements and models.

Authors of [11] focus on the provision of free Internet access to mobile users through WCN-controlled wireless LAN access points. Their scheme is built on reciprocity: a person participates in the WCN and provides free Internet access to mobile users in order to enjoy the same benefit when roaming. The proposed reciprocity scheme is compatible with the distinctive structure of WCNs: it does not require registration with authorities, relying only on uncertified free identities (public–private key pairs). This work deals mostly with the basic concepts of WCN (sharing in order to gain access on the move) and authentication aspects. In our work we use the reciprocity for users as a starting point, but we also incorporate more complex incentives like monetary revenues and endorsement from ISPs. We do not deal with practical implementation issues like authentication: we simply assume an operating network.

It has not been clear if WCNs can serve as a replacement of existing centralized networks operating in licensed bands (such as cellular networks) or if they should be considered as a complimentary service only. Authors of [12] study the dynamics of wireless social community networks using a simplistic analytical model. In this model, users choose their service provider based on the subscription fee and the offered coverage. They show that the evolution of the respective network depends on its initial coverage, the subscription fee, and the user preferences for coverage. They find that by using an efficient static or dynamic pricing strategy, the wireless social community can obtain a high coverage. Efficient pricing strategies are also studied by authors of [13]. They study the problem comprised of modeling user subscription,