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Social-connectivity-aware vertical handover for heterogeneous wireless networks

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ABSTRACT

Vertical handover mechanism for a WLAN-cellular heterogeneous network could be made efficient with the use of context aware admission control strategy. Existing admission control methods aim to provide satisfactory quality of service, but rely solely on the availability of wireless resources in the target network. We propose that the admission control in WLAN should make use of social connectivity context of users in its coverage area to classify local and global traffic. In this paper, we introduce a novel Social-Connectivity-aware Vertical Handover (SCVH) scheme, which performs admission control using connectivity graph data from the online social networking services. A higher importance of visiting node for users resident in WLAN, advocates a higher priority for granting admission. We employ graph-theoretic concept of centrality to calculate the social importance of potential handing-over nodes. By giving handover precedence to higher-centrality nodes, we achieve an optimal allocation of wireless resources in addition to improved quality of service. The proposed handover strategy offers an additional advantage of reducing global social network traffic.

1. Introduction

The next generation wireless communication is hallmarked by the convergence of all types of wireless networks. Wireless networks have become the core technology in the pursuit of ubiquitous connectivity, defined by the vision of *Always Best Connected* (ABC), i.e. getting the best available service at any time. Currently, very diverse types of radio access technologies are available for broadband wireless access and they all support mobility. These include wide area cellular networks like WCDMA, HSPA+, LTE, WiMAX, and small coverage WiFi networks. To realize the ABC concept, there has to be a close integration between the heterogeneous cellular and wireless local area networks (WLANs), aided by roaming agreements, so that the users can connect to the best service available at their location. To exploit full advantage of the available heterogeneous access technologies, the consumers have to use smartphones, which are being equipped with higher computing capacity and intelligent functionalities. Today, the smartphones have already occupied a major share in the worldwide mobile phone market (VisionMobile, 2012).

For mutual operation of heterogeneous WLAN and cellular networks, a voice or data session in progress, should be transferred seamlessly across the networks by a process known as vertical handover (VHO). A vertical handover could be triggered by the user mobility or network-preference, but the handover success is always subjected to access grant from the target network operator. Because wireless resources (bandwidth, radio channels) are costly and scarce, only a limited number of users can be served at a time while maintaining service quality. To avoid excessive load on the network, the operators enforce admission control schemes which limit the serviceable number of users. Traditional admission control algorithms have been based on availability of wireless resources (Song et al., 2007), maintaining throughput for existing users (Saad, 2011), load balancing among the collocated cells (Ma and Ma, in press) and sharing of wireless resources between new and handover sessions (Stevens-Navarro and Hamed Mohsenian Rad, 2007). Application-layer parameters are an important factor largely unconsidered in the handover research so far. Even the techniques as in Min et al. (2008) and Charilas et al. (2008) which consider application layer, limit themselves to parameters like throughput and QoS requirements.

We believe that for a handover algorithm to be truly intelligent, application layer parameters should have a role in handover and admission control decision. Investigating into the types of applications frequently used by smartphone owners in today's wireless networks, we find that lately, the most popular applications (or *apps*) have been those which provide mobile access to Online Social Networks (OSNs). Online social networking websites (e.g. Facebook, Google+, Twitter) have gained huge user-base in

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recent years, and have become one of the most popular activities on Internet (ComScore, 2011). These sites enable users to build their network of connections and share multimedia content. More interesting pieces of information propagate virally through the social network due to high number of inter-connections. A noteworthy aspect of OSN popularity is that 'mobile access' to OSNs is ever-increasing (ComScore, 2010; Facebook, 2012). Motivated by the widespread use of online social networks among mobile users, in this paper we propose utilization of *social context* in the WLAN admission control algorithms (in conjunction with parameters from lower layers). Admission to WLAN will be prioritized according to social context, and it will result in a localized social network traffic and efficient routing of social updates. To this end, the contributions of this paper are three-fold. First, we utilize the concept of centrality from graph theory to determine the social importance of a user within a graph. Second, we illustrate how the WLAN access points can act as proxy servers of OSN, which will help in localizing OSN traffic. Third, we propose a Social-Connectivity-aware Vertical Handover (SCVH) algorithm which makes admission to WLAN network dependant upon centrality score of incoming node. SCVH algorithm works well in most real world scenarios like the WiFi network of a college/university campus, a hostel accommodation, an enterprise, a conference venue, etc., where most of the members are tied to each other in a dense connectivity graph. Since most of today's electronic gadgets (smartphones, tablets, laptops, gaming consoles, etc.) are WiFi-enabled and WiFi networks are available almost everywhere, scenarios of dense connectivity graphs are fairly common to find today and increasingly so in future. We evaluate our proposed approach on publicly available OSN datasets. The simulation results indicate that social network traffic flowing out of WLAN is considerably reduced, which will translate into better QoS for end users.

Remainder of this paper is organized as follows. We start with a brief review of related research works in Section 2. Section 3 deals with the metrics used for measurement of social importance of a certain user in the graph. Next, in Section 4 we propose our Social-Connectivity-aware Vertical Handover (SCVH) for admission to WLAN network. Section 5 describes the calculation of relative weights for each metric to be used in SCVH algorithm. Simulation results are presented in Section 6, which is succeeded by concluding remarks.

2. Related work

Existing handover techniques do not cater for the effects of application layer parameters on handover and overall system performance. In case of a WLAN-cellular integrated system, the simplest of the proposed admission control methods is WLAN-first scheme (Song et al., 2007), in which all users are handed over to WLAN as soon as they enter its coverage area. This method is easiest to implement but it does not utilize the available resources optimally. Lee et al. (2009) proposed a modified scheme to admit only selected handover candidate users so that QoS is maintained. Admission is granted according to a probability which is low for highly mobile cellular users, and high for slow or stationary users. Advantage of this scheme is that unnecessary handovers are prevented and QoS experience of WLAN users is not adversely effected.

Kim et al. (2010) have studied a traffic management policy which sets the probability of migrating to WLAN based on the traffic load in the WLAN and the distance of the users from the cellular base station. Those users which are at a larger distance from the base station require higher resources to maintain QoS, so they are prioritized for admission to WLAN. A similar technique (Ma and Ma, in press) exploits VHOs for network load balancing but with an additional aspect that the radio resources of all networks within the system are viewed as being shared in a resource pool.

Another explored dimension of admission control problem is the sharing of wireless resources between incoming handoff sessions and new sessions, as in Sgora and Vergados (2009) and Zhao et al. (2011). Because handoff dropping is considered more unpleasant to a user than blocking of new calls, the handoff users are given a high priority for WLAN admission. Multiservice admission control was studied in Martinez-Bauset et al. (2011), where authors presented a scheme to independently control resource sharing of each service class between new and handoff sessions. An overall view of existing vertical handover and admission control methods in heterogeneous wireless systems (e.g. Ali and Pierre, 2009; Yang et al., 2008; Stevens-Navarro et al., 2008; Garmonov et al., 2008) reveals that handover algorithms rely either on the lower layer parameters like signal strength, signal-to-noise ratio, packet delay, or call-level parameters like call-dropping and blocking probability.

Recently, the research community has shown a lot of interest in the topic of online social networking due to the rising popularity of OSNs. Roussaki et al. (2012) have proposed that context-awareness in wireless and mobile communications has to be revisited to embrace social networking concepts. Mathieu et al. (2012) have put forward the concept of information-centric networking, where the aim is to distribute information as efficiently as possible. Working along the similar lines, Poese et al. (2012) investigate how content delivery networks can be optimized for social networking traffic. To the best of our knowledge, there has been no attempt so far to integrate social context in handover management. We presented the basic idea of a social-network-assisted vertical handover in Haider et al. (2012). We made use of centrality measures in OSNs to formulate a preliminary notion of social importance metric. In the current paper, we have expanded the idea, proposed a refined definition of social importance, did more rigorous experiments and included more results.

3. Social importance metric

The social networks, in general, and online social networks (OSNs) in particular, are mathematically represented as a *graph*. The social network members are represented as nodes/vertices, while the relationships among them are represented as graph edges. In most of the OSNs, this relationship is simply termed as *friendship*. The graph edges can be a weighted and/or directed, depending on the type of social network. Popular social networks like Facebook create a dual-way friendship which can be modelled as undirected edge. Some OSNs like Twitter feature a one-way friendship which should be modelled as directed edge. For the sake of simplicity, in this work we consider only undirected graph edges with Boolean weights. An extension for directed graphs shall be sought after in a later work.

The number of edges (connections) of a node is known as its *degree*. A notable property of OSNs is that the degree of their users follows a power-law distribution (Mislove et al., 2007). Any graph with N nodes is mathematically represented by an *Adjacency Matrix* $\mathbf{A}$, of size $N \times N$. Each entry (i,j) in matrix $\mathbf{A}$ has a value of '1' or '0' depending on whether the nodes v_i and v_j are connected or not. The diagonal entries representing self-connections are set to zero.

All nodes within a graph have an importance associated with them, calculated by *centrality* measures (Borgatti and Everett, 2006). In social networks, centrality of a node is a measure of its prestige or influencing power in the graph. Nodes with a higher centrality value are referred to as *central* nodes. The more central a node is, the more it is responsible for the social interactions and