A Novel Vertical Handover Scheme for Diminution in Social Network Traffic

A Haider, I Gondal, J Kamruzzaman

GSIT, Faculty of IT

Monash University

Melbourne - Australia

{ammar.haider, iqbal.gondal, joarder.kamruzzaman}@monash.edu

Abstract—In a WLAN-cellular integrated network scenario, the most important point of consideration is the vertical handoff strategy applied for WLAN admission control. The admission control has previously been based on the parameters like congestion level in WLAN network. We propose a novel approach for handoff to WLAN by using connectivity graph data from online social networking services. Stronger social ties with other users advocate a higher probability of admission to WLAN. The main benefit of proposed handover strategy is diminution in global social network traffic. Simulation results prove the validity of our proposed approach against conventional methods.

Keywords—Admission Control, Social Importance Metric, Graph Centrality, Probabilistic Admission

I. INTRODUCTION

Convergence of heterogeneous wireless networks is paving the way for 4G age of ubiquitous connectivity, defined by the paradigm of ‘Always Best Connected’. This concept shall be realized, on the network side, by the integration of heterogeneous cellular and wireless LAN networks, and on the consumer side, by the use of high-end smartphones. Equipped with full internet access capabilities, these phones can host a wide variety of applications, especially the ones which provide mobile access to online social networks (OSN). Online social networking sites (e.g. Facebook, MySpace, Twitter) have gained immense popularity in recent years, with an interesting aspect that ‘mobile access’ to OSNs is ever-increasing [1].

For mutual operation of WLAN and cellular networks, a voice or data session, already in progress, should be transferred seamlessly across the two networks by a process known as vertical handover. However, to avoid excessive load on the network, call admission control is employed which limits the serviceable number of users. Traditionally, admission control has been based on wireless resources available in a cell. In case of a WLAN-cellular integrated system, the simplest admission control method is WLAN-first scheme [2], in which all users are handed over to WLAN as soon as they enter its coverage area. SuKyoung et al. [3] proposed a modified technique by making admission to WLAN probabilistic so as to avoid congestion and maintain reasonable throughput. Almost all of the existing schemes for admission control and handoff in heterogeneous

wireless systems (e.g. [4-7]), rely either on the lower layer parameters like signal strength, SINR, packet delay, or call-level parameters which are call-dropping and blocking probabilities. Application-layer parameters are rarely involved in handover decisions, and even the techniques (e.g. [8, 9]) which consider application layer, limit themselves to application throughput requirements.

Motivated by the widespread use of online social networks among mobile users, in this paper we propose utilization of ‘social connectivity profiles’ of users in the WLAN admission control algorithms. We analyze the social connectivity graph of users present in a WLAN and estimate a measure of social importance of users who request for admission to WLAN. Social Importance is estimated by calculating ‘graph centrality’ measures. According to our proposed Social-Network-Assisted Vertical Handover (SNAHV), users with high importance value are given a high priority for handover to WLAN network. Only requirement for implementing SNAHV is that connectivity graph of users should not be sparse. This condition holds true in many real world scenarios like the WiFi network of a college/university campus, a hostel accommodation, an enterprise, a conference venue, etc. In all such cases, most of the members are tied to each other, making the connectivity graph dense. We evaluate our proposed approach on publicly available OSN dataset.

Rest of this paper is organized as follows. We start with listing the metrics for measurement of social importance of a given user in a graph. Next, in section III we propose our Social-Network-Assisted Vertical Handover (SNAHV) for admission to WLAN network. Simulation results are presented in section IV, which is succeeded by concluding remarks.

II. 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 (often called *friendship* for simplicity) are represented as graph edges. The graph edges can be a weighted and directed, depending on the how accurately the relationships are modelled. For the sake of simplicity, we consider only undirected graph edges with boolean weights. 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 [10, 11]. Any graph with N nodes is mathematically represented by an *Adjacency Matrix* 'A', of size $N \times N$. This matrix has an entry of '1' at position (i, j) if nodes v_i and v_j are connected, otherwise it is '0'. Each node within a graph has an importance associated with it, calculated by *centrality* measures. There are a number of centrality measures defined in graph theory [12]. Some relevant ones are listed below. We denote the node under consideration by v_i .

- 1) *Degree Centrality*: It counts the number of adjacent (neighbour) nodes to estimate the importance of a particular node. So, the degree centrality for node v_i is defined as:

$$C_D(v_i) = \sum_{j=1}^N A_{ij} \quad (1)$$

Degree centrality should be normalized when comparing two nodes from different graphs. Denoting the normalized degree centrality by $\hat{C}_D(v_i)$, we have:

$$\hat{C}_D(v_i) = \frac{C_D(v_i)}{(N-1)} \quad (2)$$

- 2) *Betweenness Centrality*: This parameter computes the number of shortest paths in a graph that pass through node v_i . Mathematically it is represented as:

$$C_B(v_i) = \sum_{\substack{s=1 \\ s \neq i}}^{N-1} \sum_{\substack{t=s+1 \\ t \neq i}}^N \frac{\sigma_{st}(v_i)}{\sigma_{st}} \quad (3)$$

where σ_{st} is the total number of shortest paths between nodes v_s and v_t , and $\sigma_{st}(v_i)$ counts only those passing through node v_i . For a graph with N nodes, the maximum number of shortest paths, that a node can lie on, is $(N-1)(N-2)/2$. Therefore, the normalized betweenness centrality $\hat{C}_B(v_i)$ is

$$\hat{C}_B(v_i) = \frac{C_B(v_i) \times 2}{(N-1)(N-2)} \quad (4)$$

- 3) *Eigenvector Centrality*: This parameter is based on the assumption that the importance of a node is proportional to the importance of its neighbours. It is calculated from the principal eigenvector of adjacency matrix A .

$$A\mathbf{x} = \lambda\mathbf{x} \quad (5)$$

where $\mathbf{x}$ is a vector of eigenvector centrality for all the nodes and λ is the eigenvalue of A . Normalized eigenvector centrality of node v_i is the element at the i th index of vector $\mathbf{x}$, defined as

$$\hat{C}_E(v_i) = \mathbf{x}(i) \quad (6)$$

We are interested in analyzing a small subset of users from an OSN. To determine the importance of a node v_i in this subset, we propose a *social importance metric* (SIM) for any node within the social graph, defined as a combination of the three centrality measures. First, the centrality data is normalized by using a modified sigmoid function:

$$C_y^*(v_i) = \frac{2}{1 + e^{-k_y \hat{C}_y(v_i)}} - 1 \quad (7)$$

where k_y is a constant, tuned according to typical values of each parameter $\hat{C}_y$ (i.e. $\hat{C}_D$, $\hat{C}_B$ or $\hat{C}_E$). The purpose of normalization is to scale all values equally within the range 0~1. Next, the SIM parameter is calculated as a linear combination of three normalized measures

$$Y_i = \mu\{C_D^*(v_i), C_B^*(v_i), C_E^*(v_i)\} \quad (8)$$

where $\mu\{\cdot\}$ is the mean operator and Y_i is the SIM for node v_i . Here, we only consider the mean operator, but other operators like weighted average can be employed, which we will explore in a future work. The significance of SIM parameter is described in the next section.

Figure 1. Heterogeneous network scenario – a WiFi hotspot inside a ubiquitous cellular coverage, with mobile nodes represented by asterisks.

III. SOCIAL-NETWORK-ASSISTED VERTICAL HANDOVER VERTICAL HANDOVER

The proposed SNAVH scheme makes use of cross layer parameters e.g. SIM (application layer) and RSS (physical layer) for handover decision. Figure 1 highlights a scenario for SNAVH, where a WiFi hotspot is deployed inside a building, which itself lies within a broad area covered by a cellular base station. Assume that all the mobile users are members of an online social networking (OSN) service. Non-members can also be treated as members with zero degree. A roaming node that enters the WiFi coverage, tends to associate itself with WiFi to gain advantage of higher bandwidth internet access at a lower cost. But before switching to WLAN, the mobile terminal should go through

a series of physical layer parameter checks, as described in the Hybrid Vertical Handover (HVH) scheme [13]:

- Firstly, fast-travelling mobile nodes should avoid handover as they would depart WLAN quickly.
- Secondly, the signal from WLAN should have a rising trend to confirm that mobile node is indeed approaching the access point instead of just travelling along the boundary. This test is carried out using discrete fourier transform of received signal strength (RSS).
- Thirdly, the received signal level should be greater than a specific threshold, which is calculated adaptively according to the moving speed of mobile node.
- Finally, a dwell timer with adaptive duration is maintained. The first three conditions must remain true for dwell-timer period.

Once these tests are completed, the mobile node requests WLAN access point (AP) for admission to the hotspot. At this instant, a traditional WiFi AP without any QoS implementation would try to accommodate all the nodes requesting admission. If AP is QoS-enabled, then admission is subject to the availability of ample resources. We propose here that the AP can also act as a proxy server for the OSN. More generally, in a large WiFi deployment where several access points are collocated, the central Authentication, Authorization & Accounting (AAA) server can perform the job of OSN proxy. In that case, admission of an incoming node can be prioritized according to its social importance, computed by (8), a measure that indicates the incoming user's social connectivity to those already connected to WiFi. The intuition behind this proposal is that users of online social networks frequently share their status and media content (photos and videos) with their friends. Generally, the information shared by a node has to be disseminated to all other nodes that are in a relationship through the OSN. This process can be made quick, efficient and cheap with the use of AP proxy servers. Then the node X's shared information can be instantly distributed to all the friends of X who are currently inside WLAN. In the best

case, when all the friends of node X are present in hotspot, the information sharing can be totally localized.

To consider the admission request of any incoming node, the AP analyses the social graph of the nodes already present in WLAN, along with the incoming node. By analyzing the graph, the social importance metric (SIM) for incoming node is computed as discussed in previous section. Each of the centrality measures contributing to SIM has significance in how efficiently the shared information in OSN users can be disseminated. A larger degree implies more number of 'local' friends. A higher betweenness means the incoming node can help isolated entities connect together. Similarly, nodes with higher eigenvector centrality are likely to share more important data. Once the SIM is calculated, the access point uses its value to grant admission to an incoming node. The admission probability P_{adm} is calculated by the relation:

$$P_{adm}(v_i) = Y_i \quad (9)$$

Because the Y_i (SIM) values are already scaled in the range 0~1, it can be treated as admission probability of the new incoming user. When the mandatory conditions for vertical handover (signal strength value, etc.) are met and WLAN network can satisfy QoS requirements of incoming node (bandwidth, delay, packet loss, etc), admission is granted according to the SIM value. The overall procedure for SNAVH, which is a cellular-to-WLAN vertical handover, is summarized in flowchart of Fig. 2. Mathematically, we can write SNAVH as a function of four parameters:

$$SNAVH(v_i) = f(RSS_{current}, RSS_{trend}, t_{dwell}, Y_i) \quad (10)$$

where $RSS_{current}$ is the present value of RSS to be compared against an adaptive threshold, RSS_{trend} is a positive or negative value indicating signal trend, t_{dwell} is the duration of adaptive dwell timer, and Y_i is the SIM value for node i .

Figure 2. SNAVH procedure - executing cellular-to-WLAN handover

Mobile nodes that exit WLAN to switch back to cellular network, will go through HVH [13] which does not take into account social context information

IV. SIMULATION RESULTS

There have been a number of efforts for collecting datasets from online social networks by web crawling. Because the current OSNs are enormous in their volumes, the size of all public datasets is only a fraction of size of actual OSN. There are two main techniques for sampling of users from OSN - random walks and breadth-first search (BFS) visiting. Some specialized random walk samples (e.g. [14]) are more likely to be similar to the actual OSN in their properties. Unfortunately such samples cannot be used in our simulation because they do not capture full detail (connected nodes) of each discovered node. On the other hand, BFS samples although tend to have a bias of over-estimating the average degree, but they do capture a complete portion of the original graph. As mentioned previously, we are concentrating on the case of WiFi networks where users have a high degree of connectivity compared to public WiFi users. Therefore, we pick the BFS sampled datasets as they can more accurately represent connectivity of users in our targeted WiFi environment.

A simulation environment similar to Fig. 1 has been set up using MATLAB in order to test our proposed scheme. The users are scattered over a simulation area of 1 km². Some users stay stationary inside the hotspot, while the rest are roaming all over the area according to the random waypoint mobility model. Signal strength observed by the mobile nodes is calculated by a log-distance path loss model [15]. The wireless channel is subject to long-term and short-term fading effects. Social connectivity for the nodes is established by a graph sampled from the IMC'07 dataset [10]. This dataset, crawled from the Orkut online social network, captured details of 3,072,441 users connected to each other by 223,534,301 links. We used the MatlabBGL library [16] for implementation of graph algorithms.

Figure 3. Connectivity in sub-graph of users connected to WLAN

As proposed in SNAHV, the roaming nodes on entering the WLAN coverage area go through the physical layer parameter testing before they request to AP for admission. The AP then extracts a sub-graph of the nodes which are already connected to WLAN and computes the SIM of

incoming node using (8). A typical sub-graph of WLAN users is depicted in Fig 3. It can be observed that all types of users, from isolated to highly-connected ones, happen to be present in WLAN area. Admission is granted or rejected based on the SIM value i.e. the centrality measures of incoming node.

The proposed algorithm has a major aim to reduce the global social network traffic originating from WLAN. This aim is achieved successfully as evident in Table 2. It shows the volume of social network traffic sourced by the nodes present in WLAN, as a function of total number of nodes in simulation. The results prove that global social traffic volume is being considerably reduced with the introduction of OSN proxy installed on WiFi access point.

TABLE I. REDUCTION IN GLOBAL SOCIAL NETWORK TRAFFIC

No. of Users in Simulation	Original Traffic Volume (GB)	Reduced Traffic Volume (GB)
200	456.67	440.55
300	839.34	803.25
400	1152.14	1095.69
500	1436.23	1361.55

In Fig. 4, we have shown the decrease in the number of users which manage to get admission to WLAN. When the SNAHV approach is implemented, the overall utilization of WLAN is decreased because only the users which conform to the SIM criteria get admitted. The loss of users might be of the concern for the service provider, but as shown in the figure, the decrease in number of users is not substantial. A maximum difference of only 10% users is observed, meaning the benefits of proposed approach outweigh the disadvantages.

Figure 4. Number of users granted admission to WiFi

Average values of admission probabilities are plotted in Fig. 5. As the overall number of users increases, the WLAN subgraph becomes more dense, which explains the rising trend of admission probability (more connectivity - higher centrality values) with increasing number of users.

Additionally, when SIM is calculated as an average of three centrality measures, it implies higher values of admission probability, compared to when the centrality measures contribute to SIM individually.

Figure 5. Mean probability of admission

V. CONCLUSION

This paper proposes a new criterion for cellular-WLAN handover based on social networks theory. Simulations are performed on dataset obtained from a large online social network. It is observed that by prioritizing socially important nodes for admission to WLAN, a significant amount of social traffic can be reduced globally in the internet.

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