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Research Article

Vertical Handoff and Admission Control Strategy in 4G Wireless Network Using Centrality Graph Theory

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Abstract: Vertical Handoff (VHO) is a crucial mechanism for the architecture of the Fourth Generation (4G) Heterogeneous Wireless Networks (HWN), because the users of 4G-HWN are capable of switching to any network in a seamless manner. These algorithms need to be practical and true to a wide range of applications hence utilization of an application layer parameter is important to decide the handoff and admission control. As a noticeable number of OSN users increased among smart phones, this study proposes a deployment of social context incorporated with vertical handoff and admission control algorithms called VHO-AC for the 4G-HWN environment. Admission of a node is decided based on the Graph Centrality Theory, which is contributing their measures to design an application layer parameter called Social Centrality Measure (SCM). The simulation results show that social network traffic flowing out of 2G and 3G base stations is much reduced than the existing SCVH method.

Keywords: 4G wireless network, admission control, online social networks, vertical handoff, VHO-AC method

INTRODUCTION

In recent years, Internet technology has turned up as the foremost motivation at the back of innovative developments in telecommunications networks (Becchetti *et al*., 2001). These include wide-area cellular networks like WCDMA, HSPA+, LTE, WiMAX and small coverage WiFi networks. The Fourth Generation (4G) wireless communication is hallmarked by the convergence of all types of above believed wireless networks. Meanwhile, 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 most excellent available service at any time (Eva *et al*., 2003). Vision of the next-generation network is to broaden the "Always Best Connected" (ABC) notion and embrace use cases according to which user will reach any service (2G, 3G or 4G) on a single intelligent device (e.g., Smartphone, tablet, etc.) using any available network within a heterogeneous network environment consisting of open, cognitive and collaborative wireless networks (Prodromos *et al*., 2013). To exploit the full advantage of the available heterogeneous access technologies, the users have to use smart phones, which are being equipped with higher computing capacity and intelligent functionalities. To offer seamless mobility, it is comprehensible that handoff between networks either of heterogeneous technologies for 3G and beyond are described, including wireless LANs, cellular, satellite and Mobile IP (vertical handover-VHO) or of different administrative domains must be seamless when a voice or data session in progress (Wang and Prasad, 2003; McNair and Fang, 2004).

The vertical handoff algorithm allows a mobile node to change networks between different types of networks (e.g., between 3G and 4G networks) in a way that is absolutely translucent to end user applications (Mandeep and Sanjay, 2011). The most of the traditional VHO algorithms have been based on Received Signal Strength (RSS), Bandwidth, Cost function and Combination of QoS parameters (Yan *et al*., 2010). To avoid excessive load on the network, the operators enforce admission control schemes, which limit the serviceable number of users. Traditional admission control schemes have been derived from availability of wireless resources (Wei *et al*., 2007), maintaining throughput for existing users (Mohamed, 2011), load balancing among the collocated cell (Dong and Maode, 2011) and allocation of wireless resources between new and handoff sessions (Stevens-Navarro *et al*., 2008). When application layer parameters comprise a responsibility in handover and admission control, a handoff decision will be realistic and intellectual. Recently, most of the Online Social Networks (OSNs) has been accessed by the Smartphone owners rather than PC. Some of the OSN such as Facebook, Google+, Twitter, Nimbuzz has gained enormous user-base and have become one of the most admired activities on the Internet. These sites make the way for users to share images, video, etc. to their

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network of connections. Nowadays more exciting information or news broadcast virally through the OSN due to the high number of inter-connections between users.

Existing vertical handoff algorithms do not utilize for the properties of application layer parameters on handoff and overall system performance. In case of 4G wireless networks, most of the research conceded the handover based on lower layer parameters; they are followed: A simple and robust Vertical Handoff Algorithm for Heterogeneous Wireless Mobile Networks was proposed in Daojing *et al*. (2011). For the first time, Dynamic New Call Blocking Probability (DNCBP) was used as a decision parameter to execute handoff from one network to another. In Wei *et al*. (2011), a handover algorithm was presented based on stochastic control theory, which considers the time-varying and stochastic character of wireless channels. This algorithm selects one network among different alternatives in each decision epoch according to the channel state of each network, which is formed as finite-state Markov channel. The intention of this algorithm is to increase the data-rate, decrease the bit error rate and minimize the handoff delay.

The authors in Chi *et al*. (2011) have proposed a vertical handoff algorithm based on the Constrained MDP (CMDP) model, which utilized the concept of policy iteration and Q-learning algorithms. Location, velocity of the mobile node and available resources in different networks were participated in the decision-making process. Our previous works also were proposed in Christopher and Jeyakumar (2012, 2013a) for vertical handover in 4G heterogeneous wireless networks. In Christopher and Jeyakumar (2012), a direct vertical handover was proposed in fewer congested situations by adopting fuzzy logic and neural network into account. This scheme was supportive of make the handover decision when congestion in the network is massive. The extension of this study is presented in Christopher and Jeyakumar (2013b); this vertical handoff strategy was presented based on Received Signal Strength (RSS) and congestion as primary parameters. Furthermore, an efficient checkpoint based recovery scheme was presented to recover the lost data when handoff is executed. A set of QoS parameters are available bandwidth, end-to-end delay, jitter and bit error rate was presented with fuzzy rules in Kantubukta *et al*. (2012) to capture vertical handoff decision. An efficient and novel Preference Ranking Organization Method by Similarity to an Ideal Solution (PROMSIS) vertical handoff algorithm was projected for heterogeneous wireless networks in Shengmei *et al*. (2013). Motivation of this present study is observed from the recent work (Christopher and Jeyakumar, 2013b); the authors have proposed a vertical handoff methodology to improve the data rate, which is based on the data usage of the mobile user.

On the other hand, further investigated aspects of the admission control problem are the allocation of wireless networks between incoming mobile node and existing nodes. In Qinglin *et al*. (2011) the authors proposed a fundamental Call Admission Control (CAC) scheme for one-hop IEEE 802.11 Distributed Coordination Function (DCF) networks in heterogeneous networks. Because higher handoff dropping probability is considered more disagreeable to a user rather than blocking of new calls, the handoff users are given a high priority for WLAN admission. In Jorge *et al*. (2011), the authors projected a method to allocate the resources independently between new and handoff sessions. In recent years, many researchers have publicized more attention in the area of online social networking due to the increasing popularity of OSNs among mobile users. In Roussaki *et al*. (2012), the authors have proposed that context-awareness in wireless and mobile communications has to be revisited to embrace social networking concepts. In Mathieu *et al*. (2012) the authors have presented the information-centric networking concept and achieved efficient distribute information system. Recently, the authors of Ammar *et al*. (2013) approached that a handover algorithm to be truly intelligent, there should have a role for application layer parameters in the handover and admission control decision. Thus, they have introduced a novel Social-Connectivity-aware Vertical Handover (SCVH) scheme, which performs admission control using connectivity graph data from the OSN services. They utilized the concept of graph centrality theory to derive the social importance of a user within a graph. Centrality measures were used to quantify social connectivity and it was further used in the handover decision where a bunch of mobile users tried to connect with a WiFi hotspot.

This study mainly deals with the Vertical Hand Over (VHO) on 4G Heterogeneous Wireless Network (HWN). Since the smart phones users are increasing with respect to OSN users, seamless connectivity with high data rate is required for those users. Because most of today's smart phones, tablets and laptops are portable with HWN and these networks are available almost everywhere, scenarios of dense connectivity graphs are quite familiar to find today and ever-increasing in the future. Therefore, we propose the deployment of social context incorporated with vertical handoff and admission control algorithms for 4G HWN. The main contributions of this study are two-fold. First, we examine the weight or importance of a user based on Centrality Graph Theory (CGT), which utilizes Degree Centrality (Cd), Betweenness Centrality (Cb), Closeness Centrality (Cc) and Eigen vector Centrality (Ce) from the CGT. Second, we propose a Vertical Handoff algorithm integrated with Admission Control (VHO-AC) which makes admission to 2G, 3G and 4G access points reliant on centrality weight of the incoming nodes. The lower layer parameters are RSS, Link Expiration Time (LET) and congestion included with application layer parameter facilitates the VHO-AC method to decide VHO. The proposed VHO-AC method is efficient for the congested 4G networks, where every user tries to enter 3G and/or 4G network.

The simulation results show that social network traffic flowing out of 2G and 3G base stations is much reduced than the existing method.

MATERIALS AND METHODS

Centrality Graph Theory (CGT): The Online Social Networks (OSNs) are very popular and in common, mathematically represented with a graph. Few of them, are modeled as directed graph, because they create a dual-way friendship; for example, Facebook. Some OSNs such as Twitter, Google+ and Twitter features a one-way friendship which should be modeled as directed graph. The entities are the nodes and an edge connects two nodes if the nodes are linked by the relationship or friendship that describes the network. If there is a degree associated with the friendship, this degree is represented by tagging the edges. In this study, we consider only the undirected graphs of Facebook users, because applying the centrality measures on the directed edges increase the computational complexity. The degree of a node is calculated as the number of edges or connections presented to a node. A graph with N nodes can be mathematically denoted by an Adjacency Matrix A, of size N X N. Each entry (i, j) in matrix A has a value of '1' or '0', which depends on whether the node Pi and Pj are connected each other or not. The diagonal entries representing self-connections are set to zero. In social networks, centrality of a node/vertex is a measure of its relative importance in the graph. Therefore, importance or power of a node is decided by the centrality values. There are four central measures of centrality: degree, Betweenness, closeness and eigenvector, which decide the social importance of a node in this study.

Degree centrality: Degree Centrality of a node is defined as the number of link incident to a node. Therefore, Degree of centrality of a node is calculated as followed:

$$C_D(pi) = deg(pi) \tag{1}$$

Normalized degree of centrality is:

$$C_d(pi) = \frac{\deg(pi)}{(N-1)} \tag{2}$$

Thus, a node with high degree centrality denotes that the node has higher number of 'local' friends, which translates into more localized social traffic.

Closeness centrality: In mutually connected graphs, there is a distance between every node, which can be regarded as the length of their shortest paths. Closeness Centrality of a node pi is defined as the calculation of how long it will take to spread information from pi to all other nodes consecutively. Closeness centrality is defined as follow:

$$(pi) = \frac{1}{avg(L(pi,pj))} \tag{3}$$

where, L (p_i, p_j) denote the shortest path between two nodes.

Betweenness centrality: Betweenness centrality of a node is defined as the number of times the particular node proceeded as a bridge along the shortest path between two other nodes presented on the graph. The Betweenness of a vertex υ in a graph G: = (V, E) with V vertices is calculated as follows:

$$C_B(pi) = \sum_{s \neq v \neq t \in V} \frac{\sigma_{st(pi)}}{\sigma_{st}} \tag{4}$$

where, σ_{st} is the total number of shortest paths from node s to node t and $\sigma_{st(pi)}$ is the number of those paths that pass through pi. The Betweenness may be normalized by dividing through the number of pairs of vertices not including v, which for directed graph is (n-1) (n-2) and for undirected graphs is (n-1) (n-2) /2. Therefore, normalized form of Betweenness Centrality:

$$C_b(pi) = \frac{C_B(pi)}{(n-1)\,(n-2)/2} \tag{5}$$

A node with higher Betweenness centrality means that the particular node can help isolated clusters of the graph to connect together.

Eigenvector centrality: Eigenvector centrality of a node is defined as a calculation of the influence of a node in a graph. This parameter is based on the assumption that neighbors of highly connected nodes are also important. It is calculated from the principal eigenvector of adjacency matrix A:

$$Ax = \lambda x \tag{6}$$

where, x is a principal eigenvector of matrix A and λ is the corresponding largest eigen value of A. Normalized eigenvector centrality of node p_i is the element at the i^{th} index of vector x, defined as:

$$C_e(p_i) = x(i) \tag{7}$$

A node with higher eigenvector centrality is considered as the important node which shares more data because they are directly connected to high-ranking nodes or higher degree nodes.

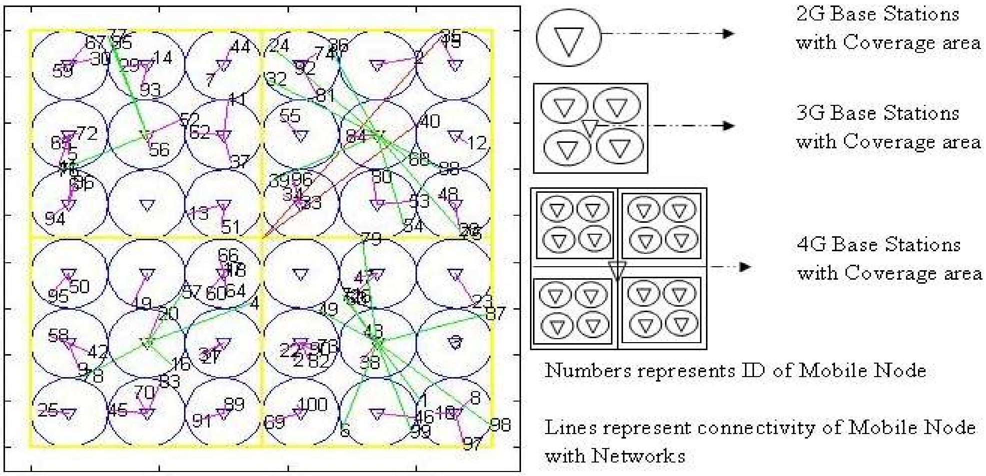

Fig. 1: 4G heterogeneous wireless network system model

System model: In Fig. 1 simulation of our 4G-HWN system is presented. The total area, A covers one 4G, N numbers 3G and M numbers of 2G base stations with P numbers of mobile nodes; therefore, $N<<M<<P$. The coverage area of each base station is pretended with radius R. We assume that all the P's are Smartphones and the users of OSN services. Initially, P mobile nodes are randomly distributed on A with random velocity, V (speed of a mobile node per second):

$$V\ (pi) = \frac{D[b(pi)-a(pi)]}{T} \tag{8}$$

Here, $a(pi)$ is current Position of the node p_i, $b(pi)$ is previous Position of the node p_i, D is euclidean distance and T is time taken to travel from the position a to b. When a mobile node p_i Є P is traveled with the same velocity and positioned in location a (a is any point lies on R), the Link Expiration Time (LET) of p_i is followed as:

$$LET\ (pi) = (R - a) * V\ (pi) \tag{9}$$

The proposed VHO-AC scheme analyzes the following lower layer and application layer parameters such as RSS, velocity, LET, Congestion, Data usage and Social Connectivity Weights. Velocity and LET of a mobile node is calculated using the Eq. (1) and (2) in every movement. Congestion is an advanced parameter to investigate the capacity and traffic of base stations. In this method, C_{2G}, C_{3G} denotes the congestion of 2G and 3G base stations, respectively i.e., number of mobile nodes connected within the base station. Data usage of a mobile node is evaluated from the Eigen vector centrality values. A mobile node with higher eigenvector centrality values is to be expected to share more data as they are directly connected with the high degree-ranking nodes. Therefore, data usage of the mobile nodes can be amplified with the higher eigenvector-ranking nodes.

The existing (Ammar *et al*., 2013) Social-Connectivity-aware Vertical Handover (SCVH) was proposed for the environment of heterogeneous networks where a WiFi hotspot resides within the coverage of a cellular network. This method has adopted the application layer parameter from CGT concept with lower layer parameters RSS, moving speed, coverage radius, handover delay to handover the mobile node which comes towards WiFi. Moreover, it has reduced the social network traffic flowing out of WiFi hotspot by applying the Admission Control mechanism. In this study, we have expanded the idea to execute the vertical handoff in 4G-HWN environment; the motivation of this work can be acknowledged as follows:

- The users of 4G-HWN is capable of switching to any network at any time in a seamless manner.
- A mobile node with high velocity or speed can be handoff to 3G or 4G base stations quickly; accordingly, they should avoid handover in the first place.
- Social Connectivity aware Vertical Handover methods need to be improves their applications to work with 4G-HWN, because 4G-HWN consists of the number of 2G and 3G base stations.
- It should reduce the social network traffic flowing out of every base station presented in 4G-HWN.

To overcome the above-described difficulties, we propose a Vertical Handoff algorithm integrated with Admission Control (VHO-AC) scheme, which efficiently analyze the status of both mobile nodes and base station. Therefore, social network traffic can be reduced in each base station.

Social Centrality Measure (SCM): This study intends an application layer parameter based on the OSN's user centrality measures to decide both the handoff and admission control strategies. To conclude the each centrality measures of a node p_i within the social network graph, we propose a Social Centrality Measure (SCM), defined as a combination of the four centrality measures. Each of these centrality measures contributing to SCM has impact in how resourcefully the shared information in OSN users can be distributed. Based on the real calculation of centrality, they are differed in scale; so, we need to make that all centrality measures on the same scale before combining them. The idea of social network metric derivation is adopted from Ammar *et al*. (2013). To convert the measures into same scale, each centrality measure is first transformed using a modified sigmoid function:

$$C_y(p_i) = \frac{2}{1+e^{-Ky*Cy(pi)}} \quad (10)$$

where, k_y is a constant value and $C_y(p_i)$ (i.e., C_d, C_b, C_c and C_e) is the respective transformed parameter. After applying Eq. (10), all the centrality measures are transformed into the range 0-1. The minimum and maximum values of each centrality value $C_y(p_i)$ are found empirically and then k_y is chosen such that (min, max) of $C_y(p_i)$ equals to (0, 1) after the transformation. Next, the SCM parameter is calculated as a weighted sum of four measures using by Eq. (11):

$$\beta(p_i) = w_1 C_d(p_i) + w_2 C_b(p_i) + w_3 C_c(p_i) + w_4 C_e(p_i) \quad (11)$$

where, $\beta(p_i)$ is the SCM for node p_i. The weights (with sum equal to '1') should be assigned based on the relative effect of each centrality measure on the significance of user p_i. The weights to be used in Eq. (11) are calculated by Eq. (12) as follows:

$$\{w1, w2, w3, w4\} = \{\frac{rd}{R}, \frac{rb}{R}, \frac{rc}{R}, \frac{re}{R}\} \quad (12)$$

where,

$$R = rd + rb + rc + re \quad (13)$$

Let N be the number of nodes in the social network graph of current 2G base station users taken together with the potential incoming user. The full degree (i.e., number of the nodes connected inside as well as outside the current base station) of node p_i is considered as n_i.

To find the weights, this study collects a set of typical values of the four centrality measures (degree, Betweenness, closeness and eigenvector) during our simulations and then find their correlation with the percentage reduction in social traffic:

Correlation with degree centrality,
$$rd = corr\,[S^\wedge(pi)], C_d(p_i)\,] \quad (14)$$

Correlation with betweenness centrality,
$$rb = corr\,[S^\wedge(pi)], C_b(p_i)\,] \quad (15)$$

Correlation with closeness centrality,
$$rc = corr\,[S^\wedge(pi)], C_c(p_i)\,] \quad (16)$$

Correlation with eigenvector centrality,
$$re = corr\,[S^\wedge(pi)], C_e(p_i)\,] \quad (17)$$

The difference between the social network traffic before and after arrival of the node pi is calculated in Eq. (18):

$$S^\wedge(pi) = \frac{\Delta S(pi)}{S1(pi)} = \frac{S1(pi) - S2(pi)}{S1(pi)} \quad (18)$$

$$S1(pi) = f_{su} t_r U_b \left(n_i + \sum_{j=1}^{z}((\Phi)^{\text{pj}}) n_j\right) \quad (19)$$

where, $S1(pi)$ is the social traffic originating from the base station due to incoming user pi, f_{su} is the frequency of social updates, t_r is a reference time interval, U_b is the average volume of social updates in bytes, z is the number of nodes connected in the base station of the incoming node pi directly and indirectly, pj is the shortest path between pj and n_j and Φ is the resharing probability. Here, n_j denotes the degree of each of pj users, where j = 1, 2,.., z. Next, the new current network social traffic due to the incoming node is calculated using Eq. (20):

$$S2(pi) = f_{su} t_r U_b \left(m_i + \sum_{j=1}^{z}((\Phi)^{\text{pj}}) m_j\right) \quad (20)$$

where, m_j is the degree of the nodes outside of the current base station of pi.

Proposed Vertical Handoff algorithm integrated with Admission Control (VHO-AC) scheme:

Step 1: Initially, the mobile node is connected with 2G network; RSS and LET is calculated in every move. The RSS and LET should be greater than a specific threshold to stay in the same network.

Step 2: When a mobile node traveling towards the boundary of base station RSS is degraded, which show a rising development to confirm that the mobile node is certainly approaching the handoff, instead of just traveling along the boundary.

Step 3: The RSS condition remains true because LET estimates the residual duration of a mobile node with the current base station. The

LET prevents unnecessary back-and-forth handovers. Thus, LET is directly proportional to the RSS of a mobile node (LET is improved when the RSS is increased).

Step 4: When the RSS or LET of a mobile node exceeds the threshold value, handoff is initiated. Now network selection takes into account since 4G-HWN has many base stations with different technologies.

Step 5: Data usage of the mobile node is analyzed by using the eigenvector centrality of CGT because a mobile node with high eigenvector centrality needs more data rate and high bandwidth. The threshold value of data usage decides the target network to handover the mobile node. The threshold values are assigned as low, medium and high, which authorizes the algorithm to select the 2G, 3G and 4G networks, respectively.

Step 6: Once the data usage of the mobile node selected the network, the lower layer parameter congestion is checked on the selected network. When the selected network is congestion-free the mobile node broadcasts the request to target network. Suppose that the C_{2G}, C_{3G} are reached the limit of congestion; the mobile node is allowed to request the 4G network (Fig. 2).

Step 7: After the request sent to target network, admission control takes into our account, accordingly SCM of the mobile node is calculated by analyzing the social network graph. The threshold value of SCM is assigned as low, medium and high, which control the VHO-AC to accept the request.

Step 8: When admission is granted for the mobile node to connect with the target network, handoff is executed.

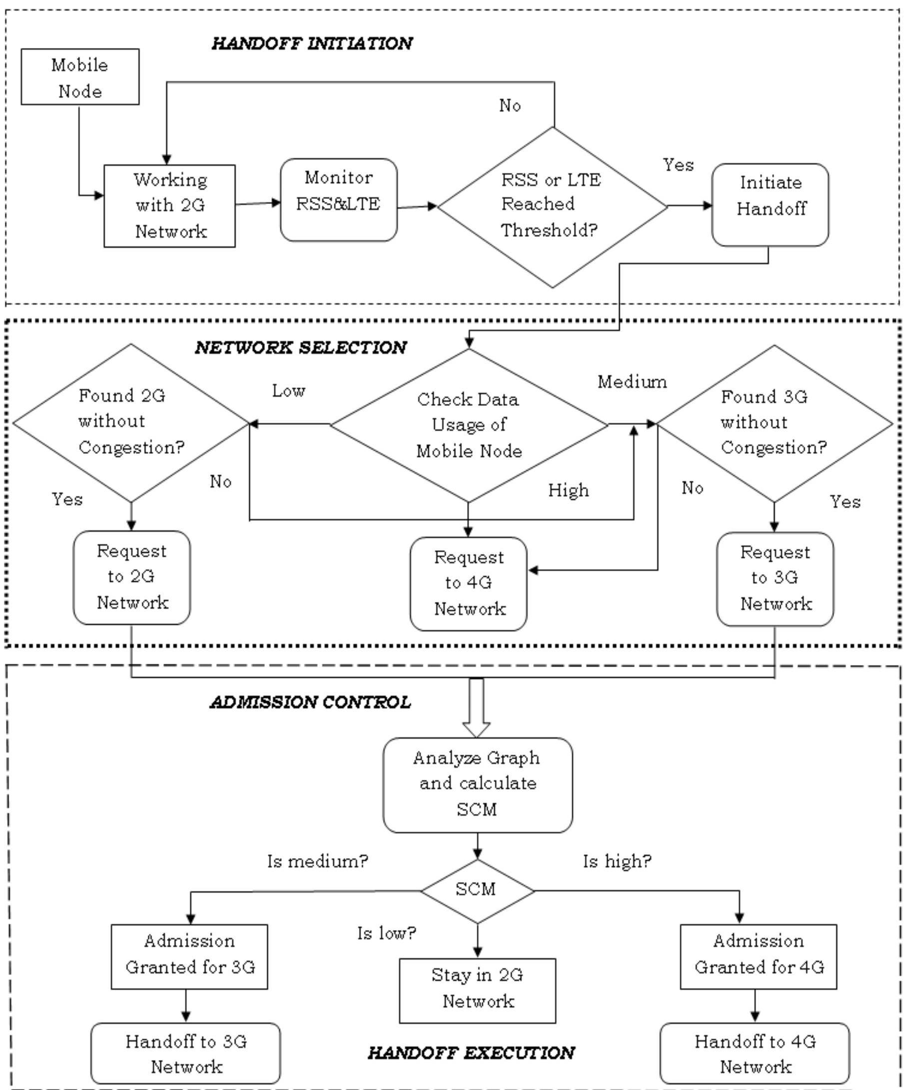

Fig. 2: Architecture of VHO-AC

RESULTS AND DISCUSSION

This section illustrates the performance evaluation of VHO-AC scheme when compared with the traditional SCVH method. We have utilized the IMC'07 dataset, which provide details of the OSN users among different popular social networks. For the simplicity of our simulation, we only adopted the data of Facebook users from the IMC'07 dataset and considered as the undirected graph. The total number of nodes taken from the dataset is, $N = 100$. A simulation environment similar to Fig. 1 has been set up using MATLAB in order to analyze the proposed scheme. Since the 4G-HWN consisted of many 2G, 3G base stations along with one 4G station, the roaming user or nodes can switch to any network at any time. As proposed in VHO-AC, initially the roaming nodes were connected to the 2G network, on initiating the handoff to any network go through the physical layer parameter testing before they request to the corresponding Access Point (AP) of the base station for admission. Using the information given to AP at the time of admission control stage, the AP calculates the centrality values and SCM parameter. Then, based on the social importance, the incoming node is allowed to execute the handoff. N users are sampled for the calculation of the social traffic volumes (S1 and S2) and centrality measures, which is then evaluated by the appropriate weights. To validate the selection of these weights, we carry out the simulation with many options of weight values. Moreover, we have adopted the SCVH method (Ammar *et al*., 2013) with the SIM calculation to compare the performance of our proposed VHO-AC scheme. Using the system model presented in the Fig. 1, SCVH method was also implemented. Table 1 and 2 shows the set of weights used in the simulation of SCVH and VHO-AC method, respectively.

To apply the proposed method in order to evaluate the admission control in both the 2G and 3G algorithm, we consider two scenarios. In scenario 1, we started the simulation from 2G networks, i.e., N nodes were randomly distributed in 2G networks. In Table 3, a set of SCM, SIM and data usage percentage values is tabulated for scenario 1 and 2, respectively. Therefore, 2G networks were overloaded with a huge number of nodes and the proposed algorithm should limit the node's handoff to 2G networks in order to reduce the traffic. The graphs 3-6 show the efficiency of the proposed VHO-AC method in scenario 1. When scenario 1 was applied, social traffic and overload of the 2G network are noticeably reduced than the existing SCVH method, accordingly the users with high SCM connected to 3G networks. Therefore, number of nodes connected with the 3G networks increased. The threshold values of the data usage and SCM.

Comparison between the proposed VHO-AC method and existing SCVH method based on the average values of admission probabilities are plotted in Fig. 3. Moreover, when the SCM and SIM are calculated using weight option 1, it has an outcome of higher admission probability, compared to when the other weight options. However, the proposed SCM parameter reduces the admission probability than the SIM parameter in cases of weight options 1, 6, 7 and 8. Due to the low admission probability, the requested target network can escaped from the high network traffic. The admission probability P_{adm} is determined by the relation of Eq. (21):

$$P_{adm}(p_i) = \beta(p_i) \quad (21)$$

Because the SCM $\beta(p_i)$ values are already scaled in the range 0-1, it can be treated as admission probability of the new incoming user.

In Fig. 4, the number of nodes connected to the 2G network is illustrated to prove the admission control

Table 1: Sets of weights to be used in SIM calculation of SCVH method

Weight option (SCVH)	w_1 (degree centrality)	w_2 (betweenness centrality)	w_3 (eigen vector centrality)
1	0.3600	0.3400	0.3000
2	1	0	0
3	0	1	0
4	0	0	1
5	0.5000	0.5000	0
6	0	0.5000	0.5000
7	0.5000	0	0.5000
8	0.3330	0.3330	0.3330

Table 2: Sets of weights to be used in SCM calculation of VHO-AC scheme

Weight option (VHO-AC)	w_1 (degree centrality)	w_2 (betweenness centrality)	w_3 (closeness centrality)	w_4 (eigen vector centrality)
1	0.2500	0.2500	0.2500	0.2500
2	1	0	0	0
3	0	1	0	0
4	0	0	0	1
5	0.5000	0.5000	0	0
6	0	0.2500	0.5000	0.2500
7	0.5000	0.2500	0.2500	0
8	0.3000	0.2000	0.3000	0.2000

Table 3: Sets of SCM/SIM and eigenvector centrality measures to be used in both scenarios

Scenario 1	Scenario 2
2G network SCM and SIM threshold low < = 0.3	2G network SCM and SIM threshold low < = 0.2
3G network SCM and SIM threshold medium <0.5>0.3	3G network SCM and SIM threshold medium <0.4>0.2
4G network SCM and SIM threshold high >0.5	4G network SCM and SIM threshold high >0.4
2G network data usage/eigen vector centrality threshold low < = 30%	2G network data usage/eigen vector centrality threshold low < = 20%
3G network data usage/eigen vector centrality threshold medium <50% >30%	3G network data usage/eigen vector centrality threshold medium <40% >20%
4G network data usage/eigen vector centrality threshold high >50%	4G network data usage/eigen vector centrality threshold high >40%

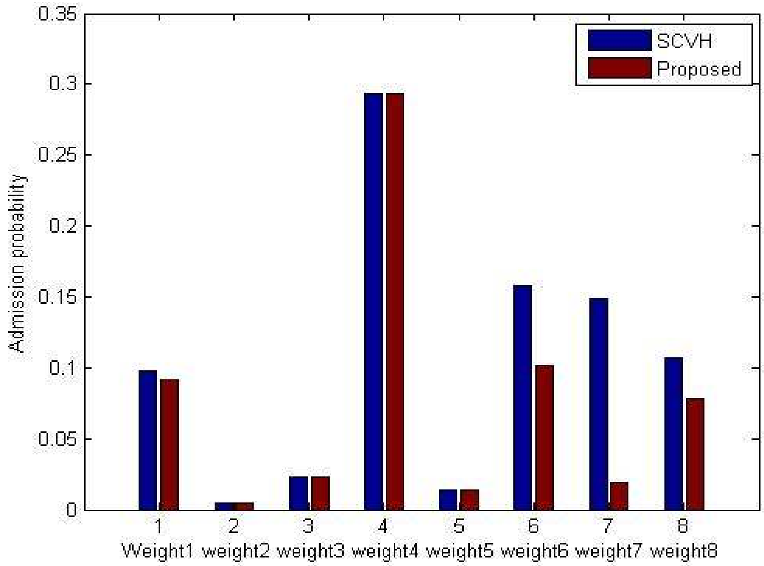

Fig. 3: Comparison of VHO-AC and SCVH method for mean probability of admission with different SCM and SIM calculation methods for scenario 1

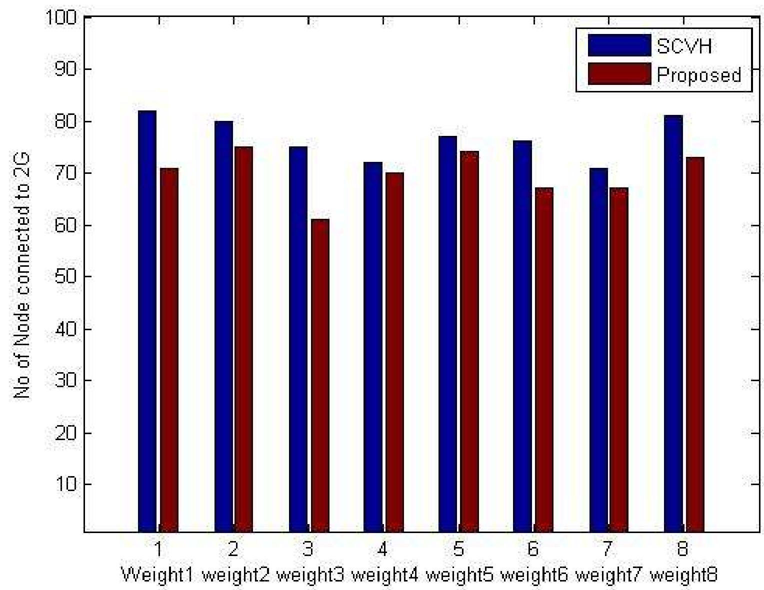

Fig. 4: Number of nodes connected to 2G networks in scenario 1

mechanism of the proposed VHO-AC. Since 2G network employed narrow bandwidth and cover a small area, it should be allocated to the limited number of users. Using the proposed scheme, lower layer parameters and application layer parameter SCM have limited the mobile users by the admission control scheme. The mobile users with the high SCM i.e., high social centrality are only allowed to connect to 2G network when it requested the 2G base station. Therefore, the VHO-AC method reduces the overload in 2G network and social traffic than the SCVH method. Figure 5 shows the percentage of traffic reduced in the 2G network when utilized both the method and proves the efficiency of our proposed algorithm.

In Fig. 6, the efficiency of the proposed vertical handoff algorithm is shown for scenario 1. When the 2G networks limit the users, they are supposed to request 3G or 4G networks. Therefore, the proposed VHO-AC method efficiently allocates the 3G base stations to the users who hold the high SCM metric. The Fig. 6 shows that the high numbers of users connected to the 3G networks and reduces the overload in the 2G networks. When compared this performance

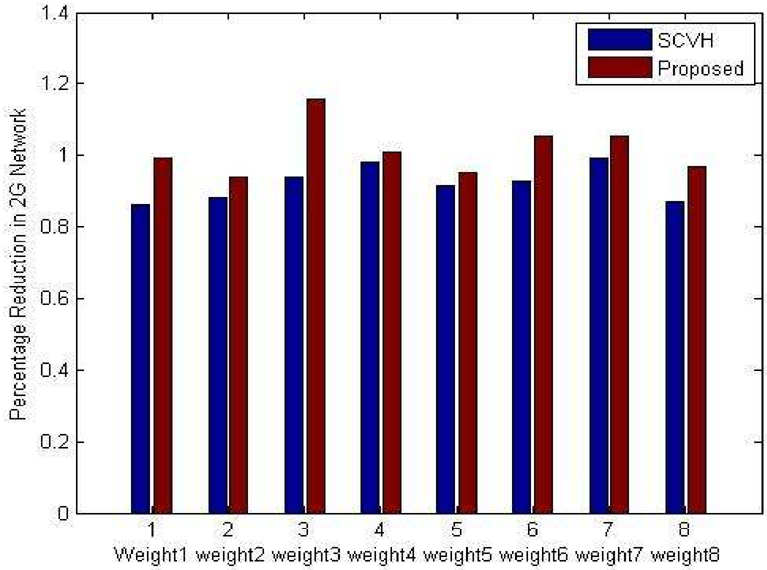

Fig. 5: Percentage of traffic reduction to the 2G network in scenario 1

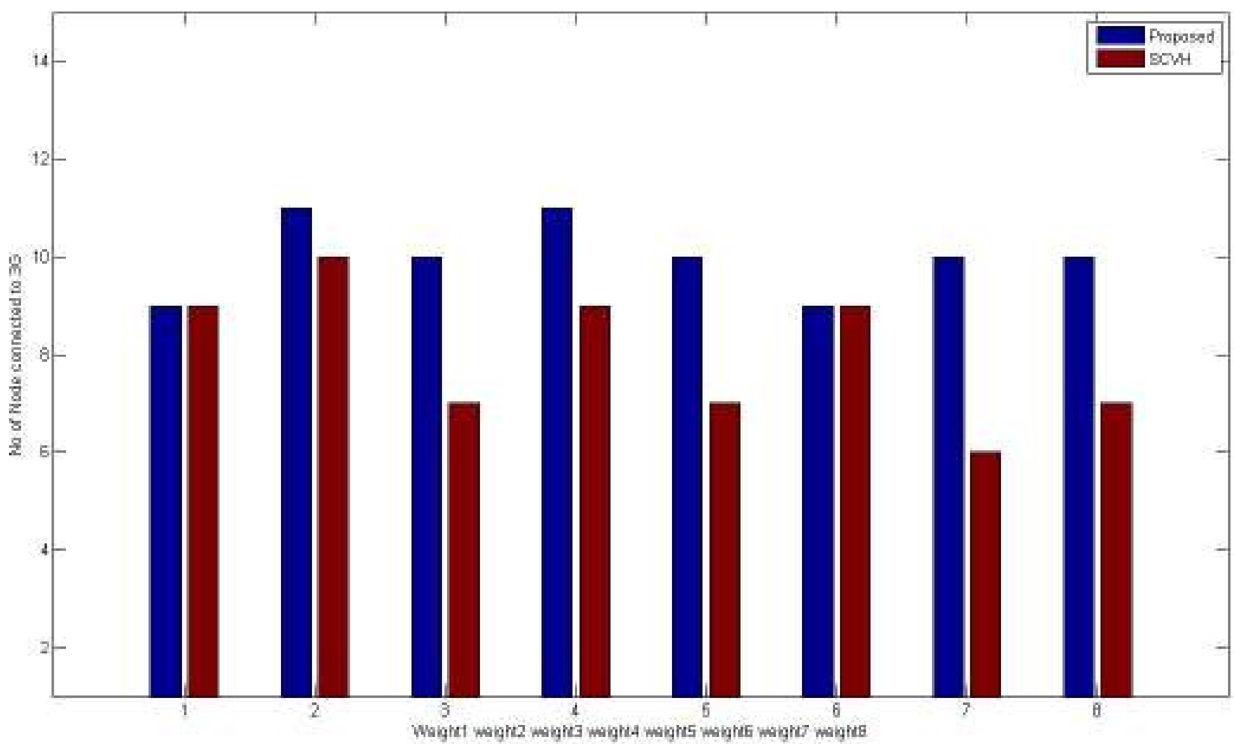

Fig. 6: Number of nodes connected with 3G networks in scenario 1

of the proposed method with the SCVH method, 3G networks leverage the more social traffic by granting the admission of mobile users with high social priority.

In Scenario 2, we started the simulation from 3G networks, i.e., N nodes were randomly distributed in 3G networks. Therefore, 3G networks were overloaded with a huge number of nodes and the proposed algorithm should limit the node's handoff to 3G networks in order to reduce the traffic. In Fig. 7, the proposed method is compared with the SCVH method when applied the Scenario 2. It shows that the number of nodes to 3G network has been reduced than the SCVH method. Percentage of the traffic reduction in the 3G network is shown in Fig. 8, which was noticeably improved when using the proposed method. In Fig. 9, the proposed method is compared with the SCVH method to show the number of nodes connected to the 4G network. As we reduced the threshold of

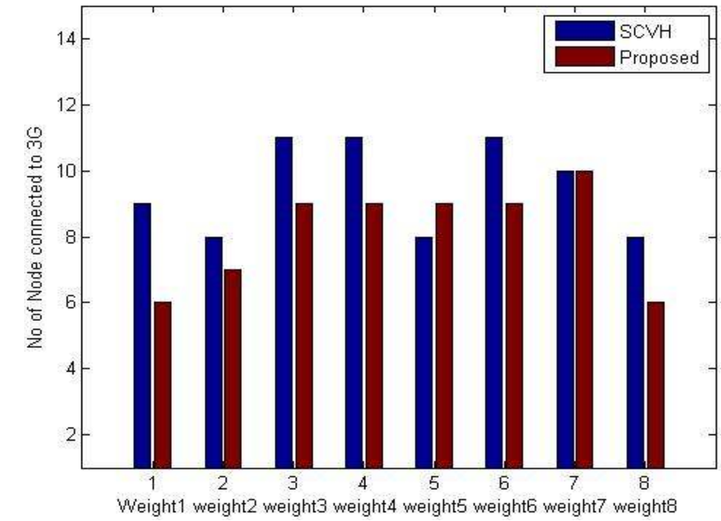

Fig. 7: Number of nodes connected with 3G networks in scenario 2

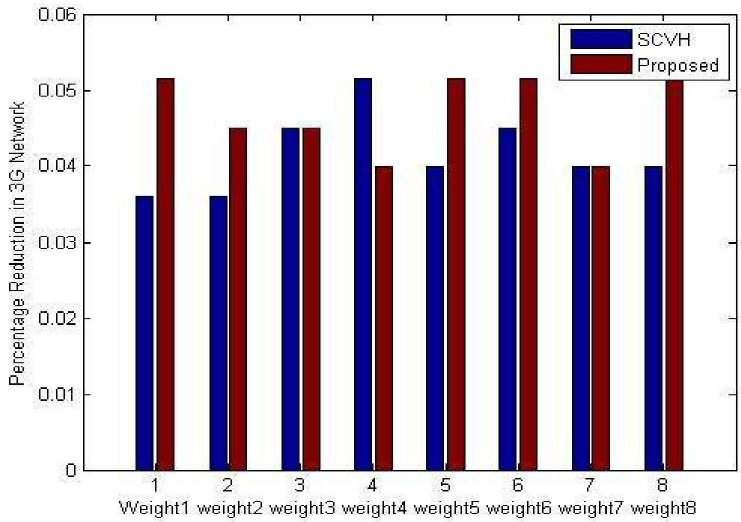

Fig. 8: Percentage of traffic reduction to the 3G network in scenario 2

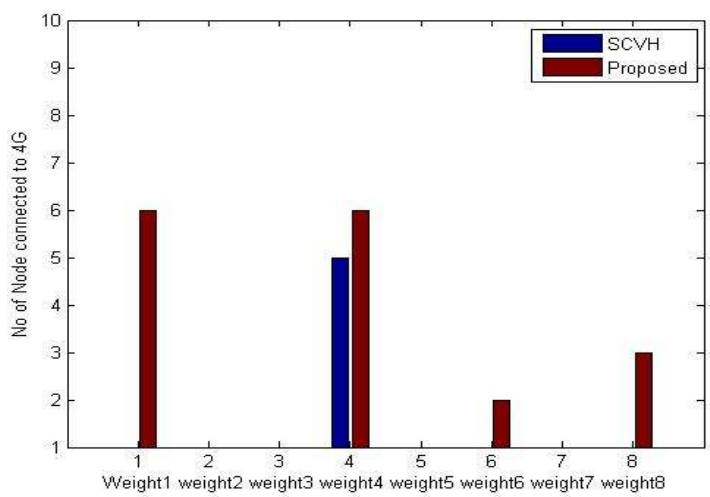

Fig. 9: Number of nodes connected with 4G networks in scenario 2

SCM and SIM parameters in Scenario 2, the nodes with the high social centrality value easily connected to 4G networks. However, using the proposed VHO-AC method, traffic of the 3G networks has been reduced than the SCVH method and the utilization of 4G network to the users with high SCM has been increased.

CONCLUSION

In this study, we have proposed a novel vertical handoff and admission control algorithms in 4G Heterogeneous Wireless Network borrowed from social network theory. In the beginning, the roaming nodes were initiated the handoff by utilizing physical layer parameters such as RSS, velocity, congestion and Link Expiration Time. To reduce the social and network traffic, admission control was executed with the help of an application layer parameter, which is derived from the graph theory. The proposed VHO-AC scheme has been evaluated on an original OSN IMC'07 dataset rather than one aimlessly generated for the simulation. Simulation results are taken by using the eight set of weight values for SCM and SIM metrics. To prove the efficiency of the proposed method, we used two scenarios in the simulation. The proposed method proved its efficiency in terms of social traffic reduction when we compared the existing SCVH method in our environment. Moreover, the proposed method is practicable in the congested 4G-HWN environment for both the vertical handoff and admission control strategies.

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