A Direction-Based Vertical Handoff Scheme

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***Abstract*— In heterogenous wireless networks, as the users move across the coverage regions of possibly-different wireless networks, they will have to switch between them. The procedure followed to determine when and how a mobile user should switch between networks of different types is known as the vertical handoff scheme. Several vertical handoff schemes have been proposed in the literature, but few of them employ the geographical nature of this problem like we do in this paper. The scheme we propose here takes the user's direction of movement into account when choosing the most suitable candidate for the handoff. When compared with existing schemes, our proposed scheme shows significant reductions in the number of lost connections and the number of unnecessary handoffs.**

***Index Terms*— Heterogenous Wireless Networks, Vertical Handoff Scheme, Mobility Model**

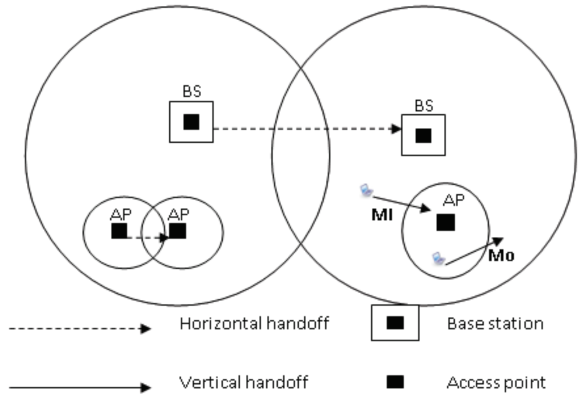

Figure 1. The different types of handoff [5]. The figure shows horizontal handoffs (between two base stations (BSs) and between two access points (APs)) as well as vertical handoffs (where mobile users move into (MI) or move out (MO) of the AP's coverage region causing handoffs between the BS and the AP).

I. Introduction

OVER the past couple of decades, the demands of mobile users have increased significantly and the nature of these demands has shifted from making simple voice calls to running applications with high bandwidth requirements. Satisfying these demands for mobile users is a very challenging problem that requires taking advantage of the many available networks (of different types). Such heterogenous wireless networks have different access technologies, architectures, protocols, operators and users [1]. Examples include the Wideband Code Division Multiple Access (WCDMA) Networks and the Wireless Local Access Networks (WLANs). Such variations have made it challenging to deal with heterogeneous wireless networks, organize them, and enable effective interaction and information sharing to provide mobile users with high quality connections. The different service demands of mobile users have made the Always Best Connected (ABC) concept important so as to allow a mobile user to get connections and services using the devices and access technologies that best suit the mobile user's communication needs as the user crosses different geographical regions covered by the different networks [2].

The *Handoff* is the process of moving a user's communication session from an access device (such as an Access Point (AP) or a Base Station (BS)) to another (in most cases, to an adjacent one) to guarantee uninterrupted communication [1]. In other words, a handoff is defined as changing the frequency, time slot and spreading code of the channel used without effecting the active session [3]. The handoff process aims at guaranteeing that a mobile user's application work properly while the user is moving from one location to another. Two types of handoff have been in use: the intra-technology handoff (*horizontal* handoff) and the inter-technology handoff (*vertical* handoff). Examples of both types of handoff can be seen in Figure 1. The figure shows the two main scenarios considered in vertical handoff. The first one is moving out (MO) of the preferred network and the second one is moving into (MI) a preferred network. Note that when switching to a different network, there may be a preferred network to switch to among the list of candidate networks (e.g., WLAN is normally preferred over a Universal Mobile Telecommunications System (UMTS) network [4]).

A handoff process can be divided into three phases: the initiation phase (radio link transfer), the decision phase and the execution phase [4]. During the initiation phase, information about access technologies, mobile users, environment and neighbors is collected. Examples of such information include Received Signal Strength (RSS) from other neighbors, Signal to Interference and Noise Ratio (SINR), distance from access devices, direction and velocity of mobile users, etc. This information will be used in the decision phase to select the best new network for handoff. This will be the main topic of this paper.

Several parameters have been proposed in the liter-

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ature for use in vertical handoff algorithms [4]. Examples include RSS, SINR, connection time, handover latency, available bandwidth, power consumption, user preferences, monetary cost, and security. In this work, we focus on reliability. When a handoff request by a mobile user fails (request is denied due to unavailability of free channels at the chosen handoff candidate) the user is disconnected. Such disconnections are intolerable in cellular networks. In fact, users prefer networks with lower bandwidth if they are more reliable (i.e., have lower disconnection probability) [6]. Additionally, we focus on providing better QoS guarantees by reducing the number of unnecessary handoffs [6].

Except for a few works, existing schemes ignore the geographical nature of this problem unlike our scheme. In our scheme, we incorporate the mobile user's movement direction in the handoff decision. By doing so, we can decrease the probability of an unnecessary handoff. Another benefit of this approach is reducing the number of handoffs to candidates with "central" locations that are close to the movement trajectories of many mobile users. This will decrease the load on these candidates, and thus, decrease the number of disconnections. These intuitive arguments of why our scheme will outperform other schemes are supported by the experiments discussed in Section V.

The paper is organized as follows. In the following section, we discuss the related works before describing the system model we use and our assumptions we make in Section III. We present our scheme in Section IV and show its performance advantage over existing schemes in Section V. Finally, we conclude our paper and discuss futures directions of this work in Section VI.

II. Related Works

Due to its importance, several vertical handoff schemes have been proposed in the literature. Below, we review these schemes.

A. RSS-Based Schemes

Zahran et al. [5, 7] proposed an adaptive lifetime-based vertical handoff (ALIVE-HO) scheme. This scheme uses the RSS to estimate the expected period of time during which the mobile user's need can be served from WLAN taking into account delay, authentication, and service initiation. Application Signal Strength Threshold (ASST) is defined as the RSS needs of applications to perform their services. In [5], a framework is proposed to evaluate the performance of the ALIVE-HO scheme. The simulation results show the tradeoff between resource utilization and the user received QoS. The authors show that by introducing the lifetime metric, the algorithm adapts to application requirements and user mobility, reducing the number of unnecessary handoffs, and improving the average throughput provided to the user because the algorithm increases the connected-duration and decreases the number of dropped users.

Yan et al. [8, 9] proposed a scheme to minimize the unnecessary handoffs and to improve the overall network utilization based on a traveling distance prediction method within a WLAN cell. The scheme uses RSS measurements to predict the time that user will spend within a WLAN cell. Their performance analysis showed that the main advantage of this scheme is that it minimizes the probability of handoff failures and unnecessary handoffs whenever the predicted traveling distance inside the WLAN cell is smaller than the distance threshold value.

Mohanty et al. [10] proposed a vertical handoff management scheme to support smooth vertical handoff management in next generation wireless systems. A cross-layer (layer 2 + layer 3) vertical handoff management protocol (CHMP) uses two RSS values from measurements of the current RSS and a dynamic RSS threshold, which is calculated by estimating user speed and predicting the handoff signaling delay of possible handoffs between a WLAN and 3G cellular networks.

Yang et al. [11] proposed a Multi-dimensional Adaptive SINR based Vertical Handoff scheme (MASVH) scheme. This scheme tries to balance the effect of SINR, required user bandwidth, user traffic cost and network utilization to improve handoff decisions by taking into account the effect of multi-attributes QoS support. The simulation results show that MASVH improves system performance by enhancing the throughput and decreasing the failed handoff probability as well as the user's traffic cost.

B. Bandwidth-Based Schemes

Ayyappan and Kumar [12] proposed a QoS-based vertical handoff scheme that depends on the available bandwidth and the user's service requirements to make vertical handoff decision between WLANs and Wireless Wide Area Networks (WWANs).

Yang et al. [6] proposed a bandwidth-based vertical handoff scheme for WLAN and WCDMA networks. This scheme uses the effect of combined SINR as a main criterion for making handoff decisions. It converts the SINR value at the access network to an equivalent value at a target network so that the handoff algorithm can determine achievable bandwidths from both access networks so as to make handoff decisions considering QoS requirements.

Ayyappan et al. [13] proposed an SINR-based vertical handoff scheme for QoS in heterogeneous wireless networks. This scheme uses SINR to improve the QoS in heterogeneous wireless networks as compared with the RSS-based vertical handoff scheme. This scheme uses SINR in calculating the throughput using Shannon's capacity theorem. The handoff is initiated when the mobile user receives a higher equivalent SINR from another network. The user connects to the network that provides better QoS. Simulation results show that the proposed SINR-based vertical handoff scheme provides higher overall system throughput as well as fewer dropped connections.

C. Other Schemes

Xia et al. [14] proposed a novel fuzzy logic vertical handoff scheme with the assistance of differential distance and a pre-decision method. This scheme makes handoff decisions between WLAN and Universal Mobile Telecommunications Systems (UMTS). The scheme consists of the following parts:

- The predictor of a Forward Differential Distance Algorithm (FDPA) that is used to get the expected next RSS.
- A Pre-Decision (PD) method applied before the handoff decision to filter unnecessary data (i.e., mobile users with high mobility or less RSS from using the WLAN) to improve the vertical handoff decision.
- The Fuzzy logic based Normalized Quantitive Decision (FNQD) method implemented to quantitatively evaluate the performance of candidate networks.

This scheme takes into account some network parameters, including velocity, current RSS, predicted RSS and available bandwidth. At the end, the optimized vertical handoff decision is made by comparing the performance evaluation values of candidate networks.

Other schemes of [15, 16] use geographical information to make vertical handoff decisions, regardless of whether this information was gathered by a GPS device or a physical layer support. In [15], the mobile user compares the distance to its current AP with the distances to the APs of neighbor cells. When the user is moving away from the current AP, it calculates the time it exits the cell. If it determines that it will be out of the cell several scans later, it decides to perform a handoff and searches for the nearest AP. If it can find an AP closer than the current AP, it switches to this AP.

The authors of [16] suggest using a location-based scheme where the mobility model of the user is used to predict its next location L after a certain period. The scheme then finds a serving AP of the location L and if it is different from the current AP, it initiates a handoff to that AP.

Finally, Chi et al. [17] proposed an analytical model for vertical handoff that uses the distance to the AP as well as Wrong Decision Probability (WDP) and the Handover Probability (HP). This vertical handoff scheme assumes that there are two networks with overlapping coverage areas. A handoff is initiated if the probability of unnecessary handoff is less than a certain threshold or when the difference in the bandwidth between the two networks is less than another threshold.

III. System Model

We now discuss the system model used in this work. We start with the signal propagation model and then go into the mobility model.

A. Signal Propagation Model

In this work we consider WCDMA networks and WLANs. Below, we discuss how to compute the Received Signal Strength (RSS) for each network type [5, 6, 13].

In WCDMA Networks. Before going into RSS computation, let us discuss the Signal to Interference plus Noise Ratio (SINR) and the Path Loss (PL). The SINR received at mobile user i when associated with WCDMA Base Station (BS) j can be represented as follows.

$$\gamma_{ij} = G_j P_j / N + \sum (G_j P_j) - G_j P_j, \tag{1}$$

where G_j, P_j and N denote respectively the channel gain between user i and BS j, the transmission power of BS j and the background noise at i. For mobile user i and BS j, the PL in dB is computed as follows.

$$\begin{aligned} PL_{ij} &= 135.41 + 12.49 \log(f_j) - 4.99 \log(h_j) \\ &+ (46.84 - 2.34 \log(h_j)) \log(d_{ij}), \end{aligned} \tag{2}$$

where d_{ij}, f_j and h_j respectively are the distance between i and j in kilometers, the frequency in MHz and the effective antenna height in meters. Now, the RSS for a BS j at mobile user i is expressed in dBm as follows.

$$RSS_C = P_j + G_j - PL_{ij} - A_j \tag{3}$$

Where P_j, G_j, PL_{ij} and A_j respectively are j's transmission power in dBm, the transmitted antenna gain in dB, the total path loss in dB, and the connector and cable loss in dB.

In WLAN Networks. Similar to the above, we start with SINR and PL before going into the RSS. The SINR received at mobile user i when associated with WLAN Access Point (AP) k can be computed as follows.

$$\gamma_{k,i} = G_k P_k / N + \sum (G_k P_k), \tag{4}$$

where G_k, P_k and N denote respectively the channel gain between mobile user i and AP k, the transmitting power of AP k and the background noise at i. For mobile user i and BS j, the PL in dB is computed as follows.

$$PL_{ik} = L + 10n \log(d_{ik}) + S \tag{5}$$

where L, n, d_{ik} and S respectively are the constant power loss, the path loss exponent with values between 2 and 4, the distance between i and k, the shadow fading which is modeled as Gaussian with mean $\mu = 0$ and standard deviation σ with values between 6 and 12 dB depending on the environment. Now, the RSS for a AP k at mobile user i is expressed in dBm as follows.

$$RSS_W = P_k - PL_{ik} \tag{6}$$

Where P_k and PL_{ij} respectively are the transmission power in dBm and the total path loss in dB.

B. Mobility Model

In addition to the popular Random Waypoint model (RWP), we propose a variation of RWP to help us gain a better understanding of the characteristics of our scheme. Below, we discuss both models.

The Random Waypoint (RWP) Model is widely used due to its simplicity [18]. In this model, the users are randomly distributed in the network. Each user randomly selects a destination and moves towards it in a straight line with constant velocity chosen uniformly from a predefined range, $[v_{\min}, \ldots, v_{\max}]$. When the user reaches the destination, it stops for a duration known as the pause time before choosing another destination and repeating the above steps.

The Random Waypoint with Changing Probability (RWPCP) Mobility Model is similar to the RWP model except that the former allows the user to change its direction of movement and velocity as it moves towards the destination.

IV. Direction-based Scheme for Vertical Handoff (DSVH)

As mentioned above, the proposed scheme makes use of many factors while handling the handoff process. First, a handoff decision is triggered whenever the RSS drops below a predefined threshold. Next, the access device which the user will be handed off to is selected as follows.

1) The scheme generates a candidate list of access devices that achieves the RSS threshold.
2) The scheme checks the movement direction of the mobile terminal by considering a cone with an angle of 2θ around the current movement direction (see Figure 2). Only access devices that cover this cone will be considered as future candidates. In other words, all access devices that do not cover the cone are excluded from the handoff candidate list. In case none of the candidates reside in the cone, then the scheme moves to step 4. See the appendix for more details.
3) Each time slot (see Figure 2)the scheme measures the RSS value for the candidate access devices (RSS_{NEW}) and compare it to the previous time slot RSS value (RSS_{OLD}). If the RSS_{NEW} is lower than RSS_{OLD}, that means that the signal is getting weaker with the passage of time, ergo, the mobile terminal is moving away from the access device. The scheme eliminates from the candidate list all access devices that the mobile terminal is moving away from. In case the mobile terminal is moving away from all of the candidates, then the scheme moves to step 4.
4) Finally, the scheme selects the closest access device to the movement direction line (see Figure 2) of the mobile user.

From our experiments, we found that choosing $\theta = 30°$ gives the best results; the time slot is set to one second.

V. Simulation Results

In this section, we present and analyze the experiments conducted to evaluate the performance of our proposed scheme, DSVH. We compared DSVH with the SINR-based scheme since it is one of the newest schemes and it is known to have higher throughput and lower dropping ratio compared with other handoff schemes (see Section II for more details).

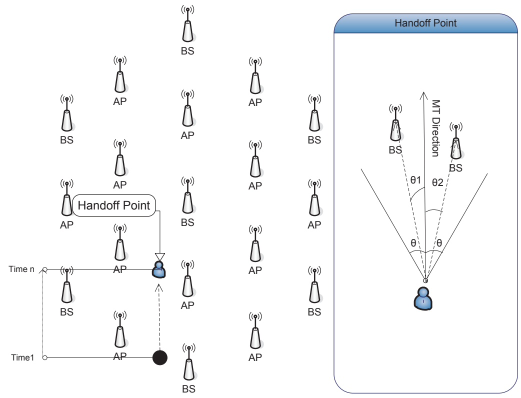


Figure 2. The handoff process in DSVH.

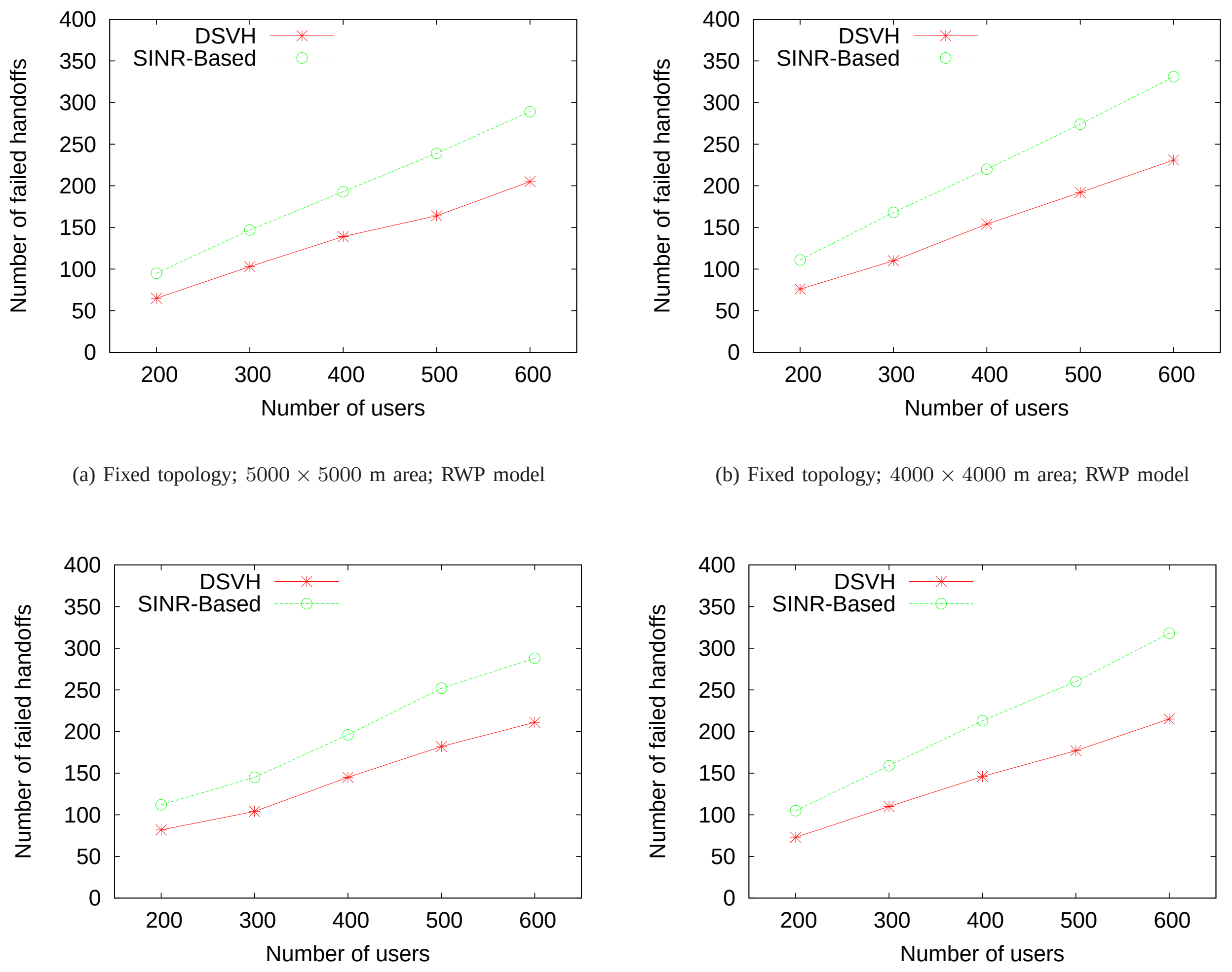
TABLE I.
Simulation Parameters.

Parameter	Values
Simulation area	5000×5000 m
Number of APs	12
Number of BSs	7
RSS threshold (WCDMA to WLAN)	-80 dBm
RSS threshold (WLAN to WCDMA)	-85 dBm
Antenna height of BS	30 m
AP transmitter power	20 dBm
BS transmitter power	33 dBm
Cable loss	5 dB
Channel gain	33 dBm
Operating frequency	894 MHz
Background noise power for WLAN	-96 dBm
Background noise power for WCDMA	-104 dBm
Bandwidth for WCDMA	5 MHz
Total noise or interference power over	16 dB

We consider a network of 7 BSs and 12 APs distributed in an area of 5000×5000 m. Previous works [6, 11, 13] have carefully placed the BSs/APs to maximize the performance of their scheme (see the left side of Figure 2). We compare the DSVH scheme with SINR-based under this fixed topology as well as a more generic topology where the BSs/APs are uniformly distributed. In the experiments below, we vary the number of mobile users between 200 and 600. The users are randomly distributed across the network area. At the beginning, each user is connected to the BS/AP with the highest SINR value. Table I summarizes the different configuration values we used in the simulations. These values were previously used with the SINR-based scheme of [6, 13].

Two metrics were used to compare the performance of DSVH and SINR-based schemes as follows.

- Number of failed handoffs: when a handoff request by a mobile user fails (request is denied due to unavailability of free channels at the chosen handoff candidate) the user is disconnected. Such disconnections are intolerable in cellular networks. In fact, users prefer networks with lower bandwidth if they are more reliable (i.e., have lower disconnection probability) [6].
- Number of handoffs: Reducing the number of handoffs is generally preferred as frequent handoffs affect the network's throughput and reduce QoS [6].



(a) Fixed topology; 5000 × 5000 m area; RWP model

(b) Fixed topology; 4000 × 4000 m area; RWP model

(c) Fixed topology; 5000 × 5000 m area; RWPCP model

(d) Fixed topology; 4000 × 4000 m area; RWPCP model

Figure 3. Comparison of the number of failed handoffs by DSVH and SINR-based schemes under various settings.

The simulation results presented in Figures 3 show the number of failed handoffs for both the DSVH and the SINR-based schemes under different settings. From these figures, we can clearly see that the DSVH outperforms the SINR-based algorithm in every setting.

In Figures 3(a) and 3(c), we test both schemes under the two mobility models discussed in Section III-B. The average improvement of DSVH over SINR-based under the RWPCP model is 31%, whereas the average improvement under the RWP model is 27%. This is due to the fact that the multiple direction changes allowed by the RWPCP model give more advantage to the DSVH since it uses a more involved algorithm for picking the best handoff candidate (see Figure 4 and the discussion associated with it). From these results, we predict that if we were to take a more realistic mobility model, the improvement ratio is likely to be higher. We are currently investigating this conjecture and the results will be part of our future work.

There are many insights related to why our proposed scheme, DSVH, outperforms the SINR-based scheme. Figure 4 depicts one such scenario. In the figure, when the user (or the Mobile Terminal (MT)) reaches the first handoff point (the red point). The SINR-based scheme will handoff to the BS that has the best SINR value, which is BS_3. Moreover, as the MT moves towards its destination, it reaches the second handoff point (the green point), and a second handoff takes place. The SINR-based scheme will handoff to the BS with the best SINR value which is BS_2. On the other hand, the DSVH scheme will behave differently. When the MT reaches the first handoff point (the red point), the DSVH scheme will nominate the access devices that reside in the cone of the MT's movement direction. So, only BS_2 will be an option for handoff and the MT will handoff to it. When the MT reaches the green point, the RSS value of BS_2 will not drop under the threshold and a second handoff will not take place. Informally speaking, since the coverage region in which the MT spends the longest period of time is the one closest to its movement direction, DSVH's selection will reduce the number of unnecessary handoffs.

As for why DSVH causes a smaller number of disconnections compared to the SINR-based scheme, it can

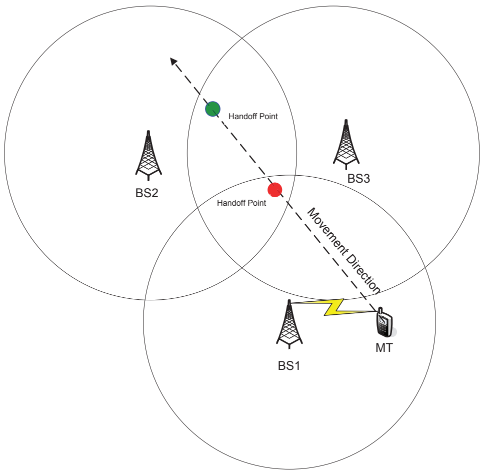


Figure 4. Example of when DSVH is better than SINR-based scheme.

be justified as follows. Consider the central region of the network and the set of BSs/APs within it. While passing through this region, the SINR-based scheme will prefer these BSs/APs due to their physical proximity to the MT. Thus, most of the MTs passing through this region will try to connect to the same small set of BSs/APs causing a high probability of disconnection. On the other hand, these BSs/APs may not necessarily be the closest to the movement trajectories for many MTs, and hence, DSVH will have no reason to give them any preference over the other BSs/APs. This will lead to a more balanced load distribution and lower probability of disconnection.

Figures 3(b) and 3(d) show that DSVH is better when decreasing the area to 4000×4000 m. The average improvements in Figures 3(b) and 3(d) are 31% and 34%, respectively. This is mainly due to the fact that reducing the area affects both the density of the network and the mobility of the users (in the sense that the users will have more frequent movement changes). This also means that the set of handoff candidates will be larger and the SINR-based scheme will choose the candidate with the best SINR value which is more likely to be out of the MT's movement direction. On the other hand, the DSVH scheme will have an advantage since it chooses the handoff candidate that is closest to the line of movement and thus requires a smaller number of handoffs (see Figure 4).

Until now, we have been using a network topology with the fixed BS/AP locations depicted in the left side of Figure 2. Note that the BSs are placed on a triangular grid and the APs are placed in the middle of the overlap regions of the coverage areas of the BSs. Such placement is in favor of the SINR-based scheme. In Figure 5(a), we use a uniform distribution of the BSs/APs. The results show that under such distribution, the average improvement gain of DSVH over the SINR-based is about 39%. Now, if we increase the number of BSs/APs (see Figure 5(b)), the average improvement gain jumps to 46%.

The plots in Figure 6 show how the number of handoffs is affected by the increase in the number of users under the various scenarios discussed above. Similar trends appear in these plots as in the ones of Figure 3; however the improvement ratios are smaller. Note that throughout Figures 6, where we consider a fixed topology, the improvement ratio is around 13%. However, when we consider uniform distributions of the BSs/APs (Figure 7(a)), the improvement ratio rises to 15%. Moreover, when the number of BSs/APs is increased to 10 and 15, respectively, the improvement ratio jumps to 18% (see Figure 7(b)).

VI. Conclusion and Future Work

In this work, we propose a new vertical handoff scheme based on the direction of the user's movement. Through extensive simulations, we show that the proposed scheme, DSVH, outperforms the SINR-based scheme, which is known to be better than other schemes [6], in terms of the number of failed handoffs. We also show that DSVH reduce the number of unnecessary handoffs.

In the future, we plan to use the user's movement history to predict its trajectory. This should enable the handoff algorithm to make better decisions especially when dealing with cases where the user keeps changing its movement direction drastically in a zig-zag fashion. Moreover, we are planning to use more realistic mobility models as well as network topologies taken from real locations of BSs/APs.

References

[1] X. Yan, Y. Ahmet Şekercioğlu, and S. Narayanan, "A survey of vertical handover decision algorithms in fourth generation heterogeneous wireless networks," *Computer Networks*, vol. 54, no. 11, pp. 1848–1863, 2010.

[2] E. Gustafsson and A. Jonsson, "Always best connected," *Wireless Communications, IEEE*, vol. 10, no. 1, pp. 49–55, 2003.

[3] X. Yan, Y. Sekercioglu, and S. Narayanan, "Optimization of vertical handover decision processes for fourth generation heterogeneous wireless networks," Ph.D. dissertation, PhD thesis, Australia, Monash University, 2010.

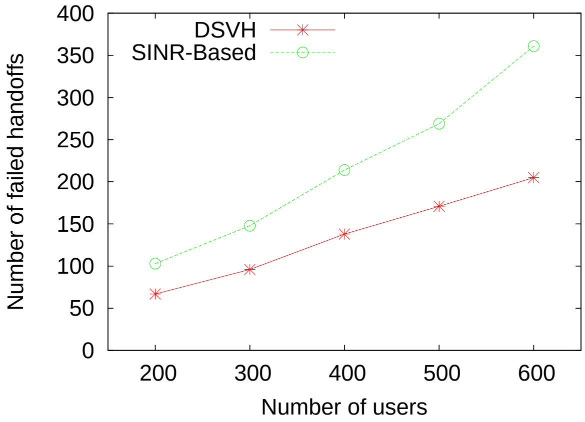
[4] K. Ayyappan and P. Dananjayan, "Rss measurement for vertical handoff in heterogeneous network," *Journal of Theoretical and Applied Information Technology*, vol. 4, no. 10, pp. 989–994, 2008.

[5] A. Zahran and B. Liang, "Performance evaluation framework for vertical handoff algorithms in heterogeneous networks," in *Communications, 2005. ICC 2005. 2005 IEEE International Conference on*, vol. 1, 2005, pp. 173–178.

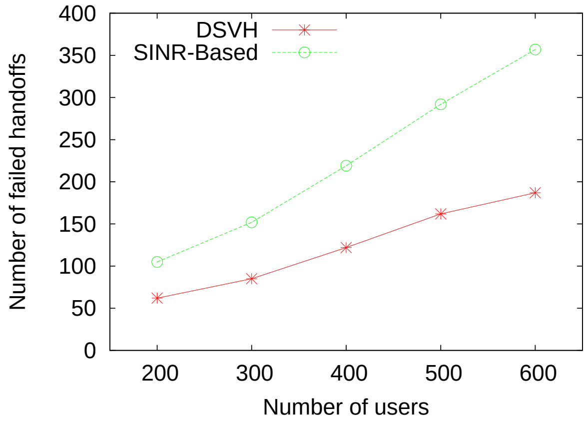
[6] K. Yang, I. Gondal, B. Qiu, and L. Dooley, "Combined SINR based vertical handoff algorithm for next generation heterogeneous wireless networks," in *Global Telecommunications Conference, 2007. GLOBECOM'07. IEEE*, 2007, pp. 4483–4487.

[7] A. Zahran, B. Liang, and A. Saleh, "Signal threshold adaptation for vertical handoff in heterogeneous wireless networks," *Mobile Networks and Applications*, vol. 11, no. 4, pp. 625–640, 2006.

[8] X. Yan, N. Mani, and Y. Cekercioglu, "A traveling distance prediction based method to minimize unnecessary handovers from cellular networks to wlans," *Communications Letters, IEEE*, vol. 12, no. 1, pp. 14–16, 2008.

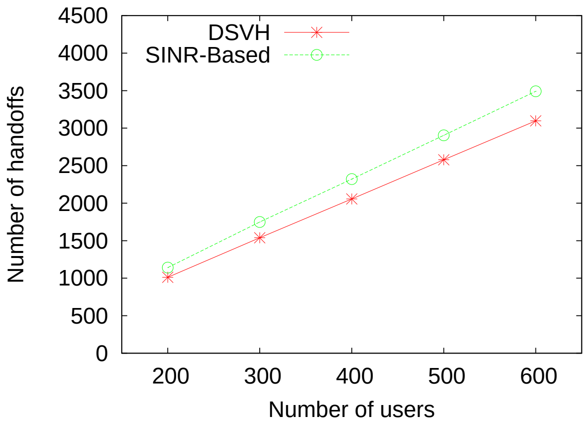


(a) Random topology with 7 BSs and 12 APs ; 5000×5000 m area; RWP model

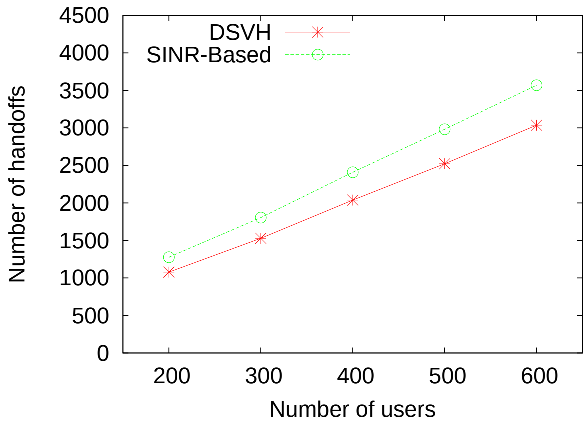


(b) Random topology with 10 BSs and 15 APs ; 5000×5000 m area; RWP model

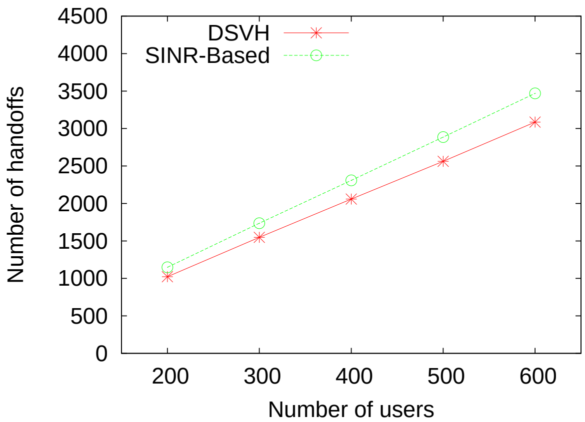
Figure 5. Comparison of the number of failed handoffs by DSVH and SINR-based schemes in random topologies with different densities.



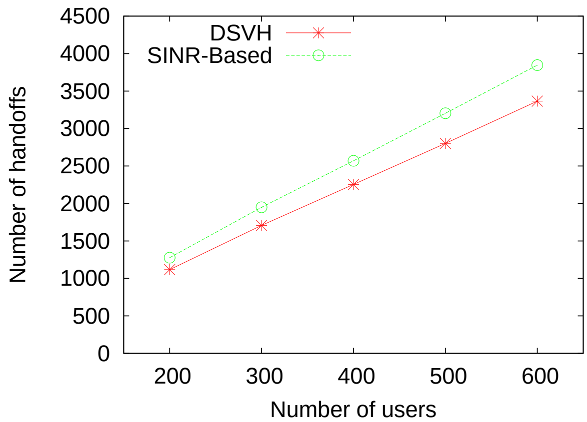
(a) Fixed topology; 5000×5000 m area; RWP model



(b) Fixed topology; 4000×4000 m area; RWP model

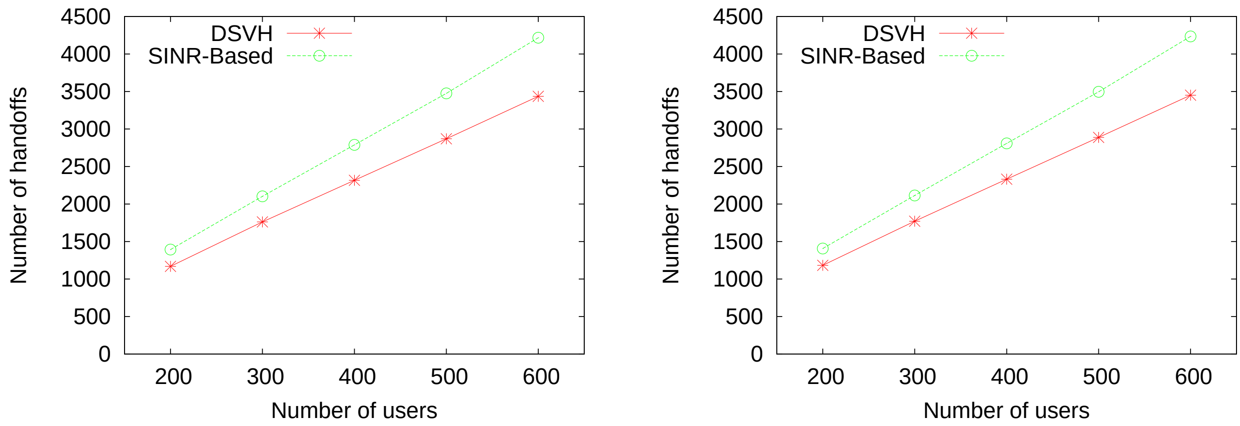


(c) Fixed topology; 5000×5000 m area; RWPCP model



(d) Fixed topology; 4000×4000 m area; RWPCP model

Figure 6. Comparison of the number of handoffs by DSVH and SINR-based schemes under various settings.



(a) Random topology with 7 BSs and 12 APs ; 5000×5000 m area; RWP model

(b) Random topology with 10 BSs and 15 APs ; 5000×5000 m area; RWP model

Figure 7. Comparison of the number of handoffs by DSVH and SINR-based schemes in random topologies with different densities.

[9] X. Yan, Y. Sekercioglu, and N. Mani, "A method for minimizing unnecessary handovers in heterogeneous wireless networks," in *World of Wireless, Mobile and Multimedia Networks, 2008. WoWMoM 2008. 2008 International Symposium on a*, 2008, pp. 1–5.
[10] S. Mohanty and I. Akyildiz, "A cross-layer (layer 2+3) handoff management protocol for next-generation wireless systems," *Mobile Computing, IEEE Transactions on*, vol. 5, no. 10, pp. 1347–1360, 2006.
[11] K. Yang, I. Gondal, and B. Qiu, "multi-dimensional adaptive sinr based vertical handoff for heterogeneous wireless networks," *Communications Letters, IEEE*, vol. 12, no. 6, pp. 438–440, 2008.
[12] K. Ayyappan and R. Kumar, "QoS based vertical handoff scheme for heterogeneous wireless networks," *Proceedings of the International Journal of Research and Reviews in Computer Science (IJRRCS'10)*, vol. 1, no. 1, pp. 1–6, 2010.
[13] K. Ayyappan, K. Narasimman, and P. Dananjayan, "Sinr based vertical handoff scheme for qos in heterogeneous wireless networks," in *Future Computer and Communication, 2009. ICFCC 2009. International Conference on*, 2009, pp. 117–121.
[14] L. Xia, L. Jiang, and C. He, "A novel fuzzy logic vertical handoff algorithm with aid of differential prediction and pre-decision method," in *Communications, 2007. ICC'07. IEEE International Conference on*, 2007, pp. 5665–5670.
[15] M. Lott, M. Siebert, S. Bonjour, D. von Hugo, and M. Weckerle, "Interworking of WLAN and 3G systems," *Communications, IEE Proceedings-*, vol. 151, no. 5, pp. 507–513, 2004.
[16] J. Zhang, H. Chan, and V. Leung, "Wlc14-6: A location-based vertical handoff decision algorithm for heterogeneous mobile networks," in *Global Telecommunications Conference, 2006. GLOBECOM'06. IEEE*, 2006, pp. 1–5.
[17] C. Chi, X. Cai, R. Hao, and F. Liu, "Modeling and analysis of handover algorithms," in *Global Telecommunications Conference, 2007. GLOBECOM'07. IEEE*, 2007, pp. 4473–4477.
[18] J. Broch, D. Maltz, D. Johnson, Y. Hu, and J. Jetcheva, "A performance comparison of multi-hop wireless ad hoc network routing protocols," in *Proceedings of the 4th annual ACM/IEEE international conference on Mobile computing and networking*, 1998, pp. 85–97.

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APPENDIX

We now discuss the details of Step 2. Specifically, we are discussing how can we decide whether an access technology device resides in the cone (as shown in Figure 2) or not. We will show this for only one case (the one depicted in Figure 8) since it is easy to generalize this to all other cases. In the figures, the current position of the MT is the point A with coordinates (x_A, y_A). m is the length of line AB which is equal to the base station coverage distance. The point B coordinates can be computed as $(x_B, y_B) = (x_A, y_A + m)$. Since $\theta = 30°$

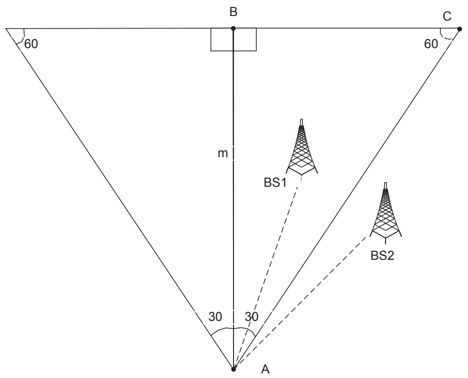

Figure 8. Movement direction cone determination.

(as mentioned above) we can use $\tan\theta = \frac{BC}{m} = 0.577$ to get $BC = 0.577m$. Thus, the coordinates for point C are $(x_C, y_C) = (x_A + BC, y_A + m)$. Now, the slope of the line AC is $Slope_{AC} = \frac{y_C - y_A}{x_C - x_A}$. Since the coordinates of each access technology device i are known, (x_i, y_i), we can compute the slope of the line Ai and if $|Slope_{AC}| < |Slope_{Ai}|$, then i resides outside the cone (see BS_2 in the figure). Otherwise, i resides inside the cone (see BS_1 in the figure).