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SINR and Cost based Vertical Handoff Scheme for K-Tier Heterogeneous Wireless Network

Amitav Panda
NIT Rourkela
Odisha India

Sarat Kumar Patra
Senior Member IEEE
NIT Rourkela Odisha India
India-769008

D P Acharya
Member IEEE
NIT Rourkela Odisha India
India-769008

ABSTRACT

The Vertical hand off (VHO) plays the key role in an integrated heterogeneous for mobility. The heterogeneous wireless network (HWN)consists od different kind of networks like 2nd Generation 2G, GSM to 4th Generation 4G Long term evolution LTE. The HWN aims to provide all kind of services like voice, data, web browsing, video streaming with interruption mobility across each tier of the network. An VHO scheme helps to achieve mobility for such HWNs. In this paper we considered the HWN as K-tier and the VHOS decision is analysed based on the best possible decision process of analytical and hierarchical process (AHP). The Saaty's 9 point decision method is applied considering the key parameters of signal to noise ratio(SINR), traffic cost, Bandwidth and in-order to avoid the ping pong effect the advanced hysteresis buffer time included during the decision process. The simulation of the proposed VHOS reflects the optimum results.

General Terms:

Vertical handoff in heterogeneous wireless network, K-tier heterogeneous wiresless network

Keywords:

VHOS, Received Signal Strength, SINR, KHWN, AHP

1. INTRODUCTION

There is a demand in next generation wireless networks in accessing all types of uninterrupted services like voice, video streaming, web browsing and telemetry with mobility for end user equipments(UEs)[1]. Different types of networks provide quality services for each of the service. Hence, integration of such heterogeneous networks necessitates to provide all kind of services to the end user's demand. The k-tier heterogeneous wireless network (KHWN) is one of the above stated heterogeneous network. The KHWN is architect by integrating the cellular networks, long term evolution(LTE) and wireless local area network (WLAN). The Vertical handoff within KHWN allows UEs to get continuous seamless connectivity with the required Quality of service (QoS) along each tier of the network. Practically coverage geometry of wireless networks is complex and challenging to estimate the QoS for vertical hand off scheme.

Earlier, vertical handoff was based on received signal strength (RSS) criterion. In this the vertical handoff decisions are made by comparing the RSS between the reset threshold and hysteresis values. Now a days, users demand all kind of services with mobility for which, the QoS have important role for providing all services (voice, video streaming, web browsing, telemetry services) with mobility. The QoS directly depends upon the signal to interference and noise ratio (SINR). So the performance of the system based on RSS is far from the desired.[1, 2] The VHOS in KHWN follows a hierarchal process which is based on pairwise comparison of QoS among each tier of the networks. We propose the Saaty's analytic and hierarchical process (AHP) in this paper for VHOS in KHWN. This process reveals the parameters as well as the various alternatives to be considered in the VHOS determination. It is followed by number of pairwise comparisons for determining factor weights and factor evaluations. [2, 3, 4]

The previous studies for vertical handoff in heterogeneous wireless networks such as combined SINR based vertical handoff (CSVH)[5], multi dimensional adaptive SINR based VHO algorithms (MASVHO)[6] and multi-attribute vertical handoff algorithm with predictive SINR using GM (1,1) use SINR,[7] user required bandwidth, user traffic cost, utilization of each access network, and user preference [8]. However, all these techniques are applied to WLAN and WCDMA networks. Applying these methods for VHOS in KHWN and considering all types of traffics independently, it is found that the results provide less throughput with no remarkable reduction in traffic cost. Hence we motivate to propose VHOS for KHWN to provide seamless vertical handoff with multi-attribute QoS. The proposed method is superior to the existing methods by three factors:

(1) It deals with different traffic types;
(2) Provides high system level throughput;
(3) Achieves low cost traffic.

The proposed VHOS uses (i)SINR, (ii)user required bandwidth, (iii)user traffic cost from k-tier access networks and (iv)user preference criterion to make hand off decision. In this method the handoff is fired when the predicted value of SINR is less than a pre-established threshold value determined by user's application or QoS restrictions [9].

The attributes and parameters are taken as per the third generation partnership project(3GPP) standard. The types of traffic considered are voice, streaming video, web browsing, telemetry. All the attributes for each type of services are also considered. In this

proposed method the analytical and hierarchical structure model (which includes goal level, criterion level, alternative level) is applied over the collected input data by pairwise comparisons of attributes. Every compared attributes on each level is again compared with adjacent attributes in order to construct the comparison decision matrix 'M' based on 9 point AHP methods [2]. For KHWN, we consider the downlink path with an arbitrary number of cellular network, broadly LTE and WLAN. Appropriate weight factors are assigned to the attributes like SINR, COST and bandwidth. These weight factors are derived from eigenvalue of the AHP. The VHOS decision is set up by breaking the decision into a hierarchy of interrelated decisions. The decision matrix is constructed comparing the adjacent of each attributes with respect to its importance. The consistency ratio(CR) of 0.1 value is acceptable[7]. Vertical handoff triggering require $CR \geq 0.1$.[5] The VHOS is established according to the attribute matrix and weight vector.
The organization of the paper is as follows. In Section II background theory behind the proposed method is given. The problem is formulated in Section III. The proposed method is discussed in Section IV. Simulation based performance assessment is done in Section V. Finally the paper is concluded in Section VI.

2. BACKGROUND THEORY

In the KHWN the transceiver for any LTE and WLAN are denoted as e-node B (eNB)and access point (AP).Considering the coverage ubiquitously for all the UEs, The transceivers can be denoted as e_{NB_i} and e_{AP_i}, respectively. If there are n and m number of transceivers for any LTE and WLAN respectively are present in the networks. Collecting all these transceivers into a matrix B, we get

$$B = [e_{NB}; e_{AP}] \tag{1}$$

where $e_{NB} = [e_{NB_1}, e_{NB_2}...e_{NB_n}]^T$
and $e_{AP} = [e_{AP_1}, e_{AP_2}, ...e_{AP_m}]^T$.
Thus, there are $m+n$ transceivers where e_{NB_i} is the i_{th} transceiver of LTE and e_{AP_j} is the j_{th} transceiver of WLAN. The indexing has been done from 1 to $m+n$ in the set of B. The best possible transceiver channel, which is having best SINR, is assigned to the user equipment UE by the KHWN with the help of an algorithm.

2.1 Signal to Interference and Noise Ratio

The throughput of the transceiver directly depends upon the SINR value of the KHWN. For this the Shannon's Theorem provides an upper bound to the capacity of a link, in bits per second (bps)[3]. The theorem is stated as

$$R_i^k = W log_2(1 + \frac{\gamma_i^k}{\Gamma}) \tag{2}$$

where, R_i^k is the maximum achievable data rate , W is the bandwidth, γ_i^k is the SINR received at the UE k when associated with the transceiver B_i and Γ is the dB gap between the uncoded M-QAM and $[capacity - coding'gain]$ [10]. Thus, the maximum achievable data rate for any LTE and WLAN link can be represented as $(R_{e_{NB,i}}^k)$ and $(R_{e_{AP,i}}^k)$ respectively. Since there is a relation between the data rate and SINR, hence SINR can be used to choose the transceiver from the KHWN. Similar to Equation(2) relation between SINR and data rate for individual LTE and WLAN in KHWN can be given as

$$R_{e_{NB_i}}^k = W_{e_{NB}}^k log_2(1 + \frac{\gamma_{e_{NB}}^k}{\Gamma_{e_{NB}}^k}) \tag{3}$$

$$R_{e_{AP_i}}^k = W_{e_{AP}}^k log_2(1 + \frac{\gamma_{e_{AP}}^k}{\Gamma_{e_{AP}^k}}) \tag{4}$$

The $\gamma_{e_{NB}}^k$ and $\gamma_{e_{AP}}^k$ are the receiving SINR for LTE and WLAN networks respectively.We can take the same equation to evaluate the down link data rate in all tiers of the KHWN, and using (3) and (4), the relationship between $\gamma_{e_{NBi}}^k$ and $\gamma_{e_{APi}}^k$ is given as

$$\gamma_{e_{NBi}}^k = \Gamma((1 + \frac{\gamma_{e_{APi}}^k}{\Gamma_{e_{APi}}^k}^{\left(\frac{W_{e_{APi}}^k}{W_{e_{NBi}}^k}\right)} - 1) \tag{5}$$

, similarly $\gamma_{e_{APi}}^k$ can be evaluated from $\gamma_{e_{NBi}}^k$.
The received SINR from ${e_{NB}}_i^k$ for $i(\gamma_{e_{NB}})$ no of UEs is converted to equivalent SINR of (γ'_{AP}) to get the same received data rate.

2.2 Cost and Bandwidth

Considering the set of SINR values S for all e_{NB}s and e_{AP}s , can be represented as

$$S = (S_{e_{NB},i} \cup S'_{AP,i}) \tag{6}$$

For a required bandwidth R_i for a user i, the minimum receiving SINR from e_{NB} and $\gamma_{min,i}$ can be calculated from Let C be the system cost vector. in order to directly associate the cost value with the SINR value, the cost per bit is converted to cost per SINR (C_{SINR}).
Let W be the network available bandwidth vector.
So the attribute matrix is as following:

$$R_a = S - \gamma_{min} 1/C_{SINR} U \tag{7}$$

3. VERTICAL HAND-OFF SCHEME

Considering the findings of SINR and cost from (7), the parameters can be set for VHOS in the KHWN. In this assumption we have considered the LTE and WLAN as the two tires of the networks as a part. So the VHOS decision making process can be set for the above assumption. We have also considered the four types of traffics in the decision making process.

—Voice
—Video Streaming
—Web browsing
—Telemetry

To rank the important decision parameters the the decision making process made hierarchical,[10] as shown is the figure-1. The previous study suggests that the AHP method is best suited for such decision making process. [11]
Following this method we have taken the overall score of a target network among KHWN, determined by the weighted sum of all the absolute values obtained from the hierarchy of the network SINR, cost and bandwidth.
In AHP the Saaty's 9 point method deals with the pairwise comparison. The VHOS attributes can be denoted by the matrix.
The selected network score for VHOS target can be obtained

$$S = \sum_{j=1}^{N} W_{f_j} r_{ij} (8)$$

where,

—$i\epsilon m$
—N - is the number of parameters
—m - denotes the number of candidate networks is KHWN
—r_{ij} value of the attributes
—j - the element of the attribute matrixm_a
—W_{fj} denotes the weight factor
which indicates the importance of each attribute.

The highest value of the weighted sum corresponds to the best target network during the VHOS. So the argument maximum value is considered for determining score of the target network can be denoted from (8) as

$$S^{*} = \arg\max_{i\epsilon m} \sum_{j=1}^{N}, W_{f_j} r_{ij} \quad (9)$$

The AHP method uses the eigenvalue of the matrix to evaluate the relative weights of decision attributes. considering the high priority attributes x_0 as the criteria and its dominant level below(d_l) have the elements, $\mathrm{x}_1, x_2, x_3, , x_l$ The relative magnitude factors in d_l are estimated through AHP pairwise comparison based on the judgements which is ranked on a Saaty 9-point scale [5]. The results of the comparison are reciprocal of the numbers. The AHP comparison matrix M_{AHP} is consider, Which is a square matrix . Now we can calculate the eigenvector vector of the matrix M_C with the maximum eigenvalue value λ_{max}.
According to the demand of traffic within KHWN between LTE and WLAN, the four types of traffic access classes of voice, video streaming, web browsing and telemetry .These four types of traffic access techniques can be represented by Matrix in AHP model as matrix M_{c1}, M_{c2} M_{c3} and M_{c4} respectively. For all classes the attributes are set according to the requirement and the AHP 9 point scale denoted in matrix form

$$M_{c1} = \begin{matrix} & c_1 & c_2 & c_3 \\ c_1 & 1 & 1/9 & 1 \\ c_2 & 9 & 1 & 9 \\ c_3 & 1 & 1/9 & 1 \end{matrix} \quad (10)$$

The M_{c1} is the comparison matrix for voice traffic of the KHWN. Similarly for video streaming M_{c2}, for web browsing M_{c3} and for telemetry M_{c4} are represented as follow:

$$M_{c2} = (\,1\,)\,1/31/9311/5951 \quad (11)$$

$$M_{c3} = (\,1\,)\,951/911/51/551 \quad (12)$$

$$M_{c4} = (\,1\,)\,551/5111/511 \quad (13)$$

Given in the above the decisions for each types of traffic specified through each type of networks, now we need to take decision for which is the best alternative for VHOS. So the pair wise comparison method of multi criteria decision making process using AHP has been adopted[8]. Here we attempted to determine the relative importance of each attributes. Applying the right principal eigenvector of matrix given the judgement with pairwise comparison and the approximation of the eigenvalue denoted by λ_x

Table 1. Represented con- sis- tency ra- tio

Traffic Type	SINR	COST	Bandwidth	CR
Voice	0.0909	0.8082	0.0909	0
Video Streaming	0.0704	0.1782	0.7514	0.0158
Web browsing	0.7143	0.1429	0.1428	0
Telemetry	0.7085	0.0603	0.2311	0

The consistency index which is the largest eigen value of the matrix can be represented as $CI = \frac{(\lambda_x - n)}{n-1}$,

—λ_x is the largest eigen value of the matrix
—n is the size of the matrix

so the consistency ratio CR, which is evaluated as $CR = CI/RCI$
to find the best judgement as the comparison is done pair wise among the attributes of networks.[6] Where random consistency index (RCI) is the average value of CI according to Saaty scale[8]. The value of RCI depends on the number criteria being compared. The well acceptance scale value for CR is $CR < 0.1$ for which the matrix are consistence as shown in table 1.

The decision matrix are considered to be consistence as we get the CR value less than 0.1. We have considered 4 types of traffic classes and the SINR, cost and bandwidth as the basic parameters for VHOS decision making process, which we got to be consistence as presented in table-1.

4. VHOS DECISION PROCESS

The proposed VHOS is considered with three parameters

(1) QoS for each types of access
(2) Available number of choices of Networks from the KHWN
(3) Considered Hysteresis time buffer to avoid unnecessary hand-off s

The QoS refer to the performance reliability of a standard communication and also the QoS model of each end user is mapped one-to-one to the ψ of the SINR. So the QoS can be denoted as

$$(QoS) = \psi(SINR) where m\epsilon 1, 2, 3...m \quad (14)$$

The above relation shows the objective of achieving QoS for end user's UE become equivalent to the achieving $(SINR)_m \geq \tau(Q_m)$, where $m = 1, 2, 3..m$ and τ is the inverse function. Hence the SINR is considered for QoS of the KHWN.
[12] In the KHWN scenario there are all kind of wireless networks

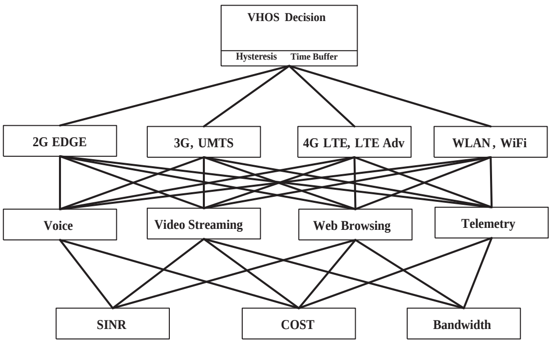

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Fig. 1. The VHOS decision process

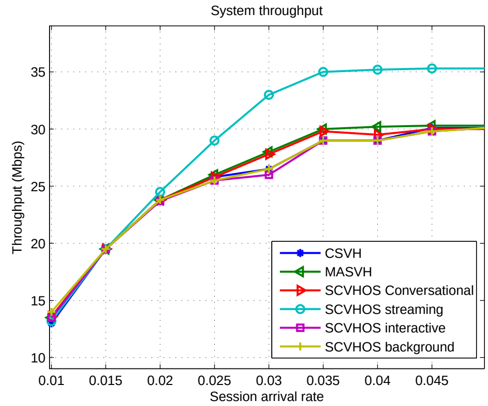

Fig. 2. [Shows the comparison of data throughput within CSVH, MASVH and SCVHOS, The four types of traffics are only contemplated in SCVHOS]

present to provide different types of services with ubiquitous presence. Here the consideration is done for one cellular network i.e LTE and WLAN. The traffic cost is also set for the VHOS decision process.[13] As shown in fig
Hysteresis time is the buffer time for an VHO to trigger, denoted as H_t. The VHO triggers when

$$\{SINR_{currentnetwork} > SINR_{predefinedthreshold} and\, if\, cost\, function$$ ork

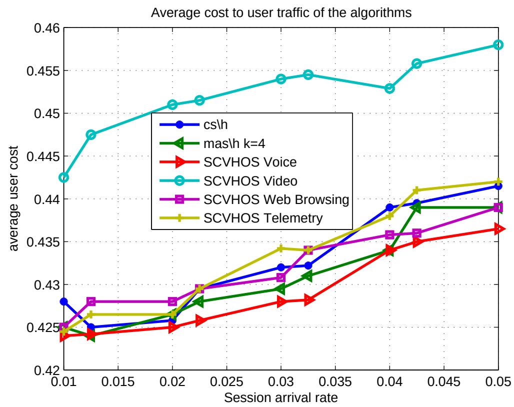

Fig. 3. [Shown the of traffic cost within CSVH, MASVH and SCVHOS, The four types of traffics are only considered in SCVHOS. For the video streaming traffic cost $([S_{eNB}, S'_{AP,i}]_{videostreaming})$]

the above condition satisfies.
The buffer hysteresis time included for determining the VHOS process H_t if the above criteria satisfies then the VHO can be triggered, considering the H_t If the handoff latency is h_l and the number of evaluations N then the VHOS triggering time can be represented as

$$VHOS_t = \frac{h_l}{e^{N_{target}-N_{current}} - 1} \quad (15)$$

The N_{target} and $N_{current}$ are the cost function values of the current and target network. Which can change dynamically over short period of time. So the H_t is modified as below, to achieve an adaptive VHO, which can deal with the dynamic KHWN environment. Considering the total evaluation count as $'n'$ and current evaluation is k. So the process will execute the same till k= N. So considering $k = 0, h_l = 0$

$$\phi = e^{N_{current}} - e^{N_{target}} \phi_k = \frac{h_l}{n} + \frac{h_l}{n(\phi_k - 1)} H_{t_k} = h_l(\frac{\phi_k}{n(\phi_k - 1)}) \quad (16)$$

The process executed until $k = N$
for $\phi_k > 1$ evaluating equation (15)we get

$$H_t = \sum_{k=0}^{N} [\frac{h_l}{N} + \frac{h_l}{N(\phi_k - 1)}] \quad (17)$$

5. RESULTS AND DISCUSSION

The performance of SINR and Cost based (SCVHOS) has been evaluated concentrating the download traffic, as the download traffic normally required bandwidth more in case of video streaming, web browsing and telemetry. The SCVHOS performance has been simulated with respect to cost and over all system throughput. The performance has been compared to the combined SINR based vertical handoff (CSVH) and multi dimensional adaptive SINR based vertical handoff (MASVH) $(k = 4)$ algorithms [11].

The simulation is performed to get the best suited overall system throughput and lowest traffic cost for access of voice, video streaming, web browsing and telemetry within KHWN of LTE and WLAN networks. Figure-1 shows the overall system throughput from which it is confirmed that system throughput is balanced in each type of traffic considering the attributes of bandwidth. The highest throughput is achieved for streaming videos as the throughput requirement is more. The cost for each access technique has been represented in the figure-2 the cost is lowest than the earlier discussed CSVH and MASVH algorithms.

For the simulation the session arrival rate for four kind of traffic are demonstrated for executing the VHO in KHWN. In addition to that here by applying modified hysteresis time in order to prevent the ping pong VHO, we found the simulation results shown in the fig.3, for voice calls, fig.4, video browsing, fig.5, web browsing and fig.6 for telemetry. The comparison with earlier methods (MASVH, CSVH) are compared and the results shows there is a considerable reduction in the total unnecessary ping pong handoff. So the simulation results validates the optimum result.

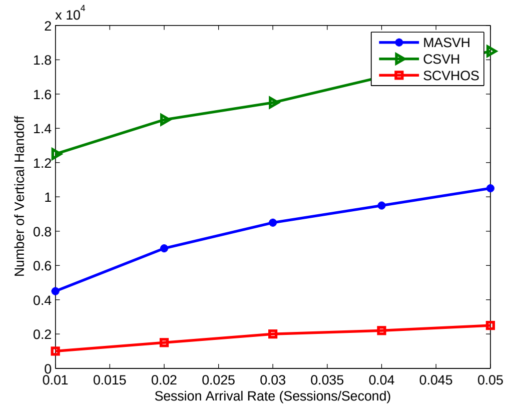

Fig. 4. The legend shows the number of VHOs for Voice calls against the session arrival rate

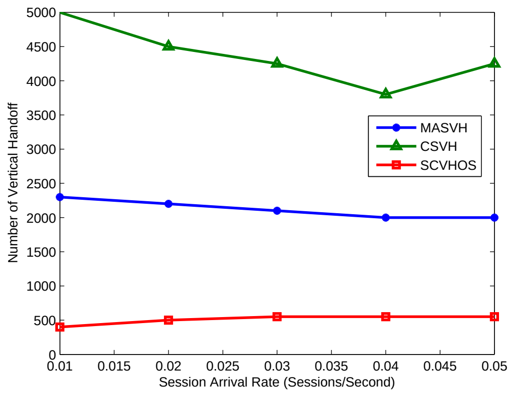

Fig. 5. The legend shows the number of VHOs for Voice calls against the Video Streaming

6. CONCLUSION

The VHOS for KHWN remains a challenging problem in order to provide voice, data, multimedia, telemetry seamlessly in each tier of the network. The proposed VHOS using SINR, Cost and Bandwidth are taken as the key parameters for VHO decision in KHWN. In this paper we have considered the LTE(4G) and WLAN as the two layers for executing the VHO. As the parameters SINR and Cost are proportionate directly to the QoS of the network,the VHOS can be considered as the QoS based handoff in KHWN. The same consideration can be validated for multiple tires of the next generation heterogeneous wireless networks. As per the simulation results the proposed scheme of VHO has been achieved QoS, better than the earlier algorithms of CSVH and MSVH and also the data throughputs are better. We deliberate the control of unnecessary handoffs by setting the adaptive hysteresis time. The simulation results are validated for four types of traffics in the KHWN. For future work other than AHP method can be applied for determining

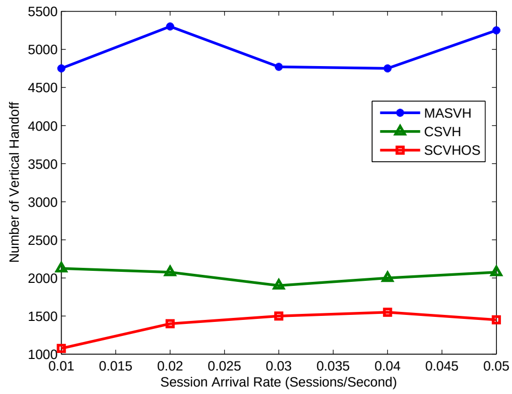

Fig. 6. The legend shows the number of VHOs for Voice calls against the session arrival rate in web browsing

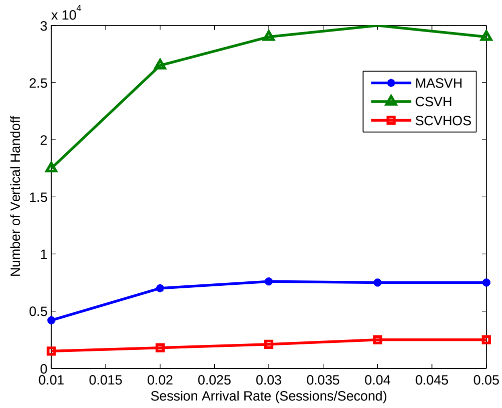

Fig. 7. The legend shows the number of VHOs for Voice calls against the session arrival rate Telemetry communication

the score of the target network during the VHO. The execution part of the VHOS can also optimized.

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