Enhanced Availability Rate and Load Balance in Emerging Heterogeneous Wireless Network Using Proactive Group Vertical Handover Algorithm

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Abstract

Future Heterogeneous Network (HetNet) will foster interoperability to achieve seamless multimedia services. To exploit the ubiquitous diversity across HetNet, Mobile Nodes (MNs) will prefer to perform Vertical Handover (VHO) for better guaranteed Quality of Experience (QoE) and optimal resource utilization. To perform VHO, the radio frequency part of the emerging wireless standards needs to accurately estimate the channel for network selection. Further in HetNet, MNs may perform VHO in group (in bus/ train) where HetNet utility increases abruptly due to simultaneous VHO requests and severely degrades the HetNet performance. Therefore, paper proposes a proactive group VHO model, whose network discovery is based on error vector magnitude (EVM) measurement which can be mobile or network controlled for optimal network selection (new attachment node). Proposed model is compared with probabilistic and non-cooperative selection schemes. Performance is evaluated in terms of link availability, packet loss rate, transmission delay, resource utilization to achieve overall optimal load balance.

Keywords: group vertical handover; GVHO; QoE; load balance; error vector magnitude; EVM; cost function; heterogeneous network; ubiquitous multimedia; link availability; packet loss rate; load balance and resource utilization

1. Introduction

MNs of ubiquitous networks experience poor Quality of Experience (QoE)/coverage due to restricted power transmission and may require Vertical Handover (VHO) to the other Access Networks (AN). VHO is defined as seamless transfer of a session between different Radio Access Technology (RAT). It is very important to complete the entire VHO process as quickly as possible or with minimum VHO latency. Limited research is available which explores VHO delays at physical layer (L1) *i.e.*, delay incurred in sensing and discovering the radio spectrum/ channel. Conventional way of spectrum sensing is based on Signal to Interference plus Noise Ratio (SINR), a scalar quantity. This paper proposes Error Vector Magnitude (EVM) to do the channel estimation and discover the radio link quality. In [1] group VHO (GVHO) is defined as a group of multi-mode terminals connecting to different RATs executing VHO nearly simultaneously as, shown in Figure 1. The overlaid area is

covered by multiple RATs and future HetNet will foster all the Mobile Nodes (MNs) to perform group mobility for *e.g.*, when a bus or train is crossing this hostile area.
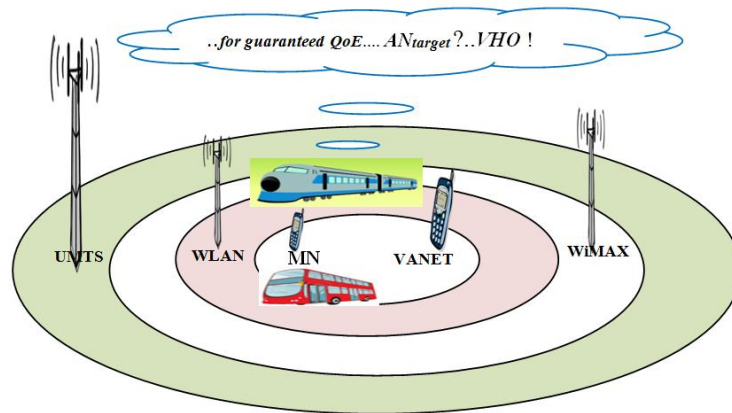
Figure 1. Heterogeneous Ubiquitous Multimedia Network

During group mobility, MNs experiences poor network coverage and link qualities, so the terminals belonging to different passengers in the bus or train may trigger handover almost simultaneously to achieve better connectivity or service. This is called as Group Vertical Handover (GVHO). In the conventional GVHO scenarios, the VHO schemes for single user may lead to system performance degradation such as inefficient resource utilization, larger transmission delay and low network availability rate, because those schemes make decision for current user without the knowledge of other user's decision, in a non-cooperative manner. Further the basis for VHO decision is mostly SINR which is inaccurately measured in power constrained transmission therefore GVHO users selfishly selects the network but ignores the influences from other concurrent VHO users. As a result, most users select same target network and degrades the performance due to network congestion.

Worth to mention that for an optimal VHO decision process, mostly a cost function is modeled by measuring various QoS metrics like Received Signal Strength Indicator (RSSI), Bit Error Rate (BER), Bandwidth, Delay, Jitter etc. To guarantee QoS, a computed cost will finally determine the best network based on complex weighing criteria as cited in [2]. There is no need to individually estimate all these QoS parameters viz. RSSI, BER, delay as no inference can be drawn if receiver gets very poor attributes or if exceeds the acceptable limit whereas Error Vector Magnitude (EVM) measurement can differentiate the poor SINR under very hostile conditions with high resolution as shown in Figure 4.

Error Vector Magnitude (EVM) is defined as the Error in modulation due to impairments in any wireless system and is first investigated by [3]. EVM measurement needs special attention as it can yield better spectrum sensing/ channel estimation. For Wideband Code Division Multiple Access (WCDMA) systems, recently a low cost EVM test methodology is investigated in [4]. EVM is more susceptible to Orthogonal Frequency Division Multiplexing (OFDM) modulation scheme where EVM is large due to loss of orthogonality, skewness and frequency offset. In Figure 2, it is shown that EVM measurement can be done before and after demodulator section of the wireless system. EVM is now an established parameter and readily available in most wireless standards in [5] and in IEEE802.16e- 2005 [6]. Reliably estimating the SINR from the measured EVM can reduce the system complexity by eliminating the need

for modules that are required to separately estimate the SINR. EVM was earlier proposed in [7] & [8] as QoS trigger.

Furthermore using EVM in the proposed model for obtaining network cost eliminates the need to compute BER/Delay/Jitter simultaneously and the entire VHO processing delay is radically reduced. Using EVM sensing and measuring mechanism, wireless link quality is assured which limits the unnecessary HO requests due to poor/low SINR which will be expedited in following sections. As per [9], VHO methods can be broadly classified into four categories according to its control methodology: Mobile Controlled (MC), Network Controlled (NC), Mobile Assisted- Network Controlled (MANC) and Network Assisted- Mobile Controlled (NAMC). In order to deal with the group mobility in vehicular communications, the concept of group vertical handover is proposed. The rest of the paper is organized as follows: Section 2 briefly presents the related literature on contemporary vertical handover algorithms and recent developments in EVM methodology. Section 3 gives complete insight of the proposed Group Vertical Handover - GVHO architecture. Section 4 presents modeling and simulation of the proposed architecture. Section 5 explains the performance analysis of the proposed model and the different attributes of the results. Finally paper is concluded with a brief note on future scope of the work followed by reference list.

2. Literature Survey

In [7-8] EVM was proposed as VHO trigger. And EVM based different VHO mechanisms were investigated. In [9] optical SNR is related with EVM and performance measure for advanced modulation formats is examined. Along with EVM other attributes are used for network selection and decision process as conventional MADM schemes. MADM schemes are explained in the following sections.

2.1 Conventional VHO Algorithms

Different vertical handover algorithms are compared and discussed in [2] where modeling is based on a common assumption that the users are coming one by one, and these schemes are proposed to select the best network for each user Furthermore, Multiple Attribute Decision Making (MADM) methods are also modeled which quantifies the weight-importance of each criterion. Later ranking of candidate networks according to importance of weights and network characteristics is done in the paper. Analytic Hierarchy Process (AHP) and the Grey Relational Analysis (GRA) are adopted to calculate the weights of various service parameters and the GRA is applied to rank the candidate networks according to QoS score function. A modified Blume method is also implemented which seems to be relatively fast and accurate. Moreover, the VHO trigger and control method including Simple Additive Weighting (SAW) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is also considered in this literature which is based on EVM measurement.

Fuzzy logic is used in [11] for VHO because it has capability to map the relationships among multiple criterions into mathematics expression and allow simultaneous evaluation of several HO criteria. Conventional algorithm lack accurate measurement and channel estimation methodology which decides the network selection and group mobility scenario. Unfortunately, there are few literatures paying attentions on how to support GVHO across HetNet in vehicular communications. In [1] the problem of GVHO is discussed and proposed three network selection algorithms with the concept of social cost introduced in game theory. In this literature, the social cost is the function of transfer latency. The first algorithm assumed that each mobile node knows the traffic load of other nodes, and the selection result is achieved with Nash Equilibrium in polynomial time.

Many other criterions, such as RSSI, PLR, BER, latency, available resources and user preferences are considered for modeling network cost function (or utility function) in most literatures. Practically these models are difficult to realize because the measurement and acknowledgements of these QoS metrics across a HetNet radically increases the overheads, computational time and overall VHO latency including network congestion. RSSI is the principle trigger to initiate VHO process based on which final network selection is made. A poor RSSI/SINR may lead to a wrong selection. Considering these critical aspects, EVM proves to be a better QoS metric. One of the major requirements in [12] for vehicular communications is that the subscribers' session or data transmission should be handed over seamlessly during vehicle movement. HetNet consists of heterogeneous radio environment with diversified RATs explained in [13]. Therefore, one problem emerges as how to provide continued connectivity as users roam across diverse RATs with reliable QoS guarantee as stated in [14-16] and enables the users to seamlessly roam over different RATs.

2.2 Wireless System Model

A digital baseband signal x is assumed to be transmitted over a communication channel with a Channel Impulse Response (CIR), as shown Figure 2. In addition, the received signal is corrupted by complex Additive White Gaussian Noise (AWGN), w. Thus, the nth received baseband symbol can be expressed as follows
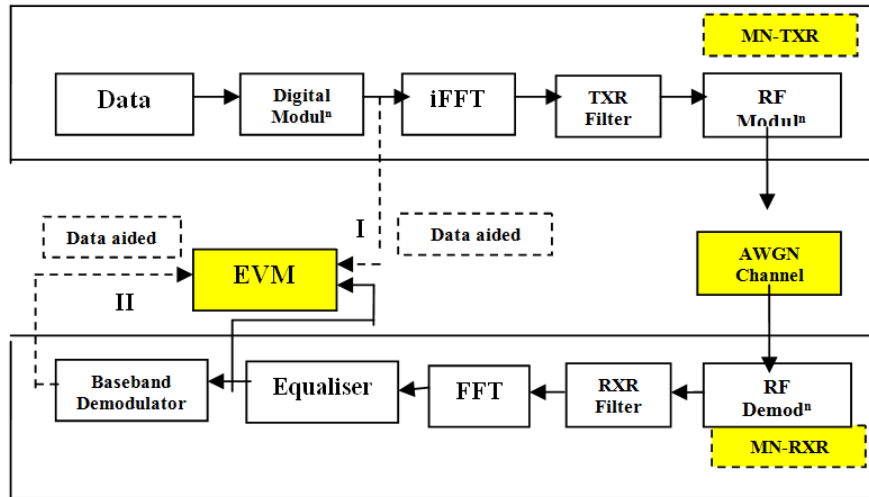
Figure 2. EVM based Wireless System Model

$$r(n) = \sum_{l=-\infty}^{\infty} x(l)h(n-l) + \omega(n) \qquad (1)$$

Note that h can also include the effects of transmitter/receiver filters in addition to the channel. If a modulation order of M is used, then x(n) $\in$ {S_1, S_2, ...S_M}. Throughout the paper, it is assumed that all symbols are sent with equal probability. The receiver, usually a measurement instrument such as Vector Signal Analyzer (VSA), acquires the signal, performs synchronization, channel estimation and equalization. The detected signal can be represented by

$$y(n) = g(n)x(n) + \eta(n) \qquad (2)$$

Where $g(n)$ and $\eta(n)$ represent the multiplicative and additive impairments to detected signal. The multiplicative impairments can be a result of channel estimation errors or IQ imbalances,

for example.   The additive impairments is usually due to thermal noise and are modeled as an *i.i.d.* complex AWGN samples with Power Spectral Density (PSD) of *No/2* for the detected signal. The first case is when the additive noise is the dominant degradation source and *g (n)* ≈ 1. EVM can be defined as the Root-Mean-Square (RMS) value of the difference between a collection of measured and ideal modulated symbols in [17]. The value of the EVM is averaged over typically a large number of symbols and it is often expressed as a percentage (%) or in dB.

2.3. EVM-SINR Relation

Testing data signals are needed to initially measure EVM and to test wireless transmitters and receivers which are practically realized by pilot signals, called as data-aided testing. Non-data aided approach is also proposed by [18] where EVM is measured without providing input data to the receiver as shown in Figure 2. Consider the detected signal in (2) where *g(n)* ≈ 1. For nondata-aided receivers, the EVM is

$$EVM_{RMS} = \sqrt{\frac{\frac{1}{N}\sum_{n=1}^{N}|y(n)-\hat{x}(n)|^2}{P_0}} \tag{3}$$

For large values of *N*, the numerator in (3) can be approximated.

Proposed model considers square QAM signals (*i.e.*, with even number of bits per symbol such as Quadrature Phase Shift Keying *(QPSK), 16-*Quadrature Amplitude Modulation *(QAM), 64-QAM, etc.*). For a QAM signal of order *M*, the modulated symbols are

$$x = (2i - k)a + j(2m - k)a, \ i, m = 0,1, ..., k \tag{4}$$
$$\text{Where } k = \sqrt{M} - 1$$

In this case, $E\{|y - \hat{x}|\} = E\{(y_R - \widehat{x_R})\} + EE\{(y_I - \hat{x}_I)\}$ $\tag{5}$

As For a normalized QAM system

$$a = \sqrt{\frac{3}{2(M-1)}} \tag{6}$$

EVM for QAM signals is given in [17] and defined as,

$$\text{EVM}_{\text{QAM}} = \left[\frac{1}{SINR} - 8\sqrt{\frac{3}{2\pi(M-1)SINR}}\sum_{i=1}^{\sqrt{M}-1}\gamma_i\,e - \frac{3\beta_i{}^2\,SINR}{2(M-1)}\right.$$

$$\left. + \frac{12}{(M-1)}\sum_{i=1}^{\sqrt{M}-1}\gamma_i\,\beta_i\,erfc\left(\sqrt{\frac{3\beta_i{}^2\,SINR}{2(M-1)}}\right)\right]^{1/2} \tag{7}$$

Where

$$\gamma_i = 1 - \frac{i}{\sqrt{M}}, \tag{8}$$

$$and \quad \beta_i = 2i - 1 \tag{9}$$

For a normalized QAM system the EVM of a QAM signal in (7) can be divided into two parts. The first part is 1/SINR, which represents the ideal EVM when no errors are introduced to the symbol detection. The second part, which in QAM case, is a sum of exponential and error functions, representing the reduction in measured EVM due to detection error. The second error part is a function of both the modulation order M and the SINR level, and it goes to zero for high values of SINR. Note that as the summation index i in (7) increases, the value of the exponential and error functions decreases rapidly. Hence, for high modulation order, an approximation of the EVM value can be obtained by considering only the first few terms of the summations. Finally, the EVM is computed by substituting the above values into (6) and repeating the same process used to calculate (7).

The EVM-SINR relation is shown in Figure 3 for different QAM orders. Figure demonstrates that at very low value of SINR below 10 dB, very less variation is observed where as EVM gives higher ranges i.e. with higher resolution.
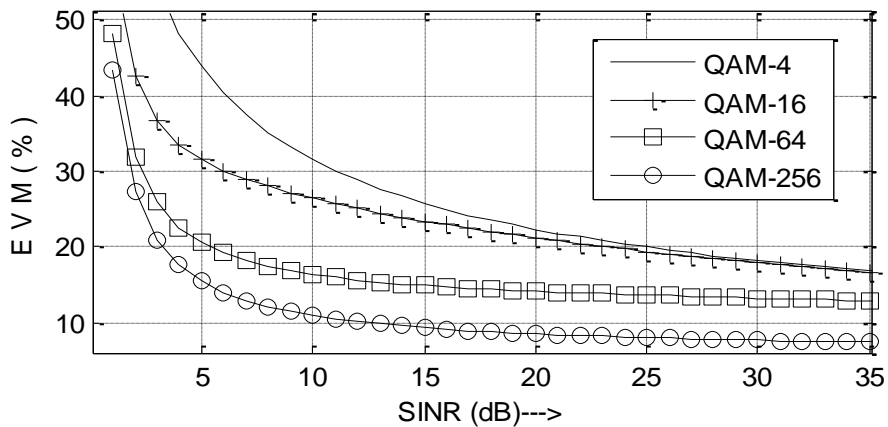
Figure 3. EVM (%) vs. SINR (dB) for QAM-order-4/16/64 *etc.*

This metric seems to be very useful in power constraint environment with very low SINR especially in case of IEEE 802.11, 802.15.4 standard and the anticipated Cognitive Radio (CR) network. Further using the wireless system models shown in Figure 2, an overall EVM computational time is computed, denoted by T^{evm}.
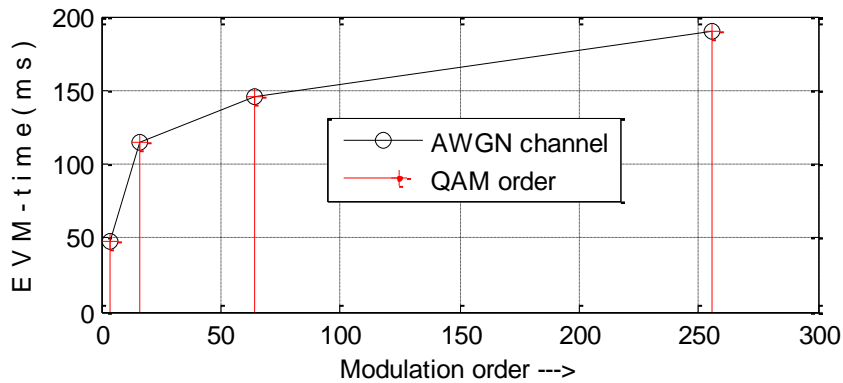
Figure 4. EVM Computational Time (ms) vs QAM-order

The computed EVM in percentage is shown in Figure 4 which is modeled in AWGN environment. For a QAM order of 16 and 64, the T^{evm} is ~ 120 and 150 ms respectively. Although this includes the discovery time but still for modeling worst case scenarios, a discovery delay ranging from (100 to 300) ms is added in this paper.
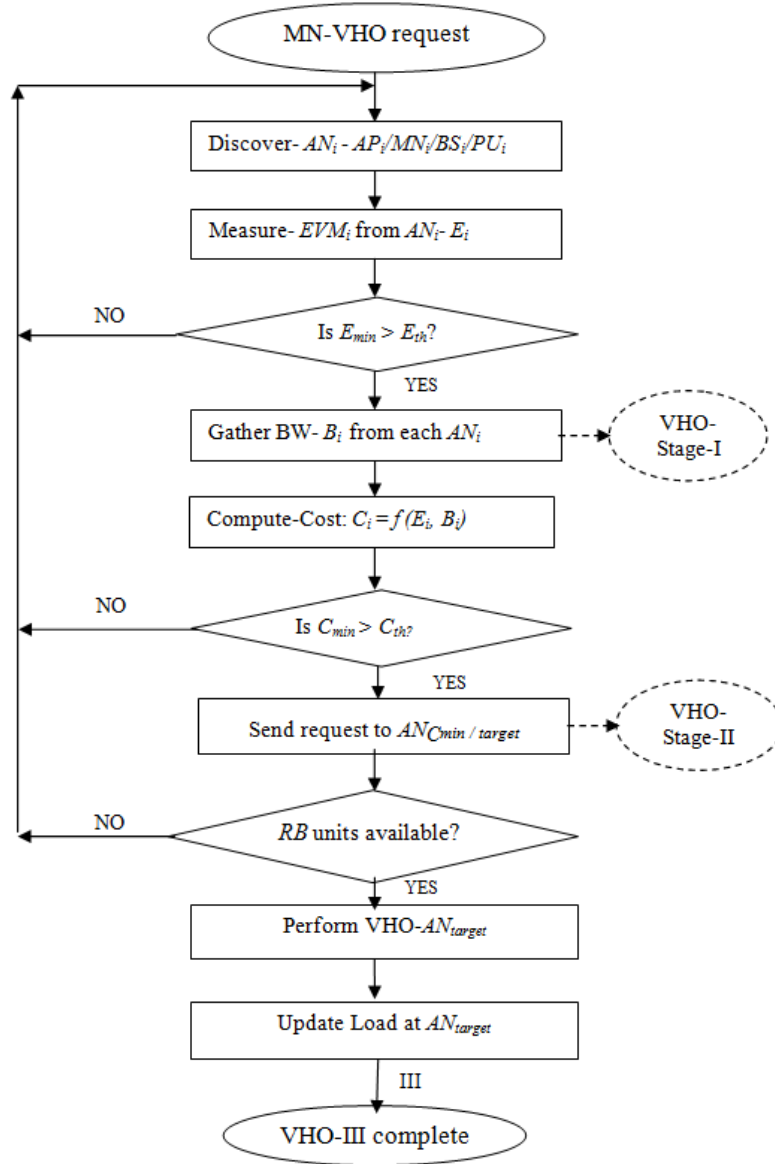
3. Proposed VHO model

Proposed algorithm is shown in Figure 5. The proposed architecture has three intermediate stages viz. VHO-I, II and III to complete VHO procedure. These stages are also depicted as three individual schemes in Section 5.Theproposed algorithm and resource block modeling is explained as follows.

3.1 Proposed VHO algorithm

VHO-I procedure completes without considering bandwidth requirements and based on EVM measurement only, MN sends request to AN_{target}. After measuring EVMs from neighboring ANs, the first proposed algorithm (MC-selfish) separates massive VHO requests in time sequence, while the second proposed algorithm distributes concurrent VHO requests into available networks according to the predefined probability distribution. Finally the third proposed model is NAMC. MN triggers the handover and the AN makes decision. Here the attachment network could be an access point of WLAN (IEEE 802.11b/g) or Base-Station of UMTS (3GPP) or BS of WiMAX (IEEE 802.16e) or an AdHoc MN of VANET/MANET.

It is worth to state that AdHoc node is independent of any controller/ infra-structure thus the network associated delays get radically reduced and VHO process completes immediately after selecting the AN with the minimum EVM. This has been shown in Figure 5 as VHO-I procedure. This procedure is selfish or non-cooperative as it doesn't wait for AN's load status. Second phase is VHO-II in which bandwidth is gathered from neighboring ANs, retaining the earlier measured EVM. Considering both the parameters, network selection is made for VHO. During this phase, MN completely exploits the merits of EVM, bandwidth and ubiquitous heterogeneity but the entire process is still non-cooperative. Due to the non-cooperative approach the overall HetNet performance degrades. After VHO-II process, the selected target AN is requested for VHO and AN finally allocate available resource block units (Time slot/ bandwidth *etc.*) and updates its resource. Finally, MN performs VHO and VHO Process completes. The complete process (including VHO-I and VHO-II) is shown as VHO-III process. In later sections it will be shown that VHO-III outperforms the other two VHO-procedures.

Figure 5. Proposed VHO Algorithm

3.2 Resource Block Modeling

It is supposed that the set N denotes the available networks in current hot spot area. For each network $i \in N$ ($i = 1, 2. . . n$), the available Resource Blocks denoted by RB_i (in Mbps) and the round trip time are T^{evm} ms, both varies with time. Set U denotes, users operating handover at a given time. For each user $j \in U$ ($j = 1, 2... m$), the required service bit rate is R_j Mbps, and it is assumed that $R_j \in R$, where R is the discrete set of allowable bit rate. Let set $U_{RT}, U_{NRT} \subseteq U$ be the set of handover users with real-time (RT) service and non-real-time (NRT) service, respectively. Various services have their special characteristics.

The real-time service is delay-sensitive, while the non-real-time service is sensitive to packet losses. Therefore, for decision making models of GVHO scenario, the goals for RT service and NRT service are different. For real-time service, its objective is to minimize the

average transmission delay of whole system, while the objective of NRT service is to minimize the average PLR. If the allocated rate approaches the available resources, the transmission delay will increase due to network congestion. Therefore, a simple fractional function is given to approximate the non-linear increase in transmission delay for the allocated rate to user j and the available resources of network $\boldsymbol{i}$ [19] as:

$$T_{ij} = \frac{\left(R_j T_j^{evm}\right)}{2\,RB_i^*} \tag{10}$$

Where RB_i^* is the available resources of network after the VHO. For NRT service, its PLR is estimated as an exponential function of packet delay distribution. Meanwhile, the unbalanced load distribution among multiple networks has influences on PLR. As a result, the

PLR is given as: $\qquad PLR_{ij} = \beta_i e^{-\frac{T_o^{evm}}{T_{ij}}} \tag{11}$

Where T_o^{evm} is the maximal tolerable delay of NRT service, T_{ij} also can be calculated as same as in (10), and β_i is factor of load balancing, which is defined as:

$$\beta_i = \frac{\sum_{i \in N} RB_i^* - RB_i}{\sum_{i \in N} RB_i^*} \tag{12}$$

4. Modeling and Simulation

Paper proposes three schemes MC-selfish, MC-probabilistic noncooperative and NAMC cooperative approaches. Modeling of schemes is explained in following section.

4.1 MC-selfish Algorithm: based on Time Window

MN just selfishly selects the "best" network regardless of the influences from other concurrent handover MNs. At first these simultaneous arrived VHO requests are separated in time sequence. This method is first proposed in [1] and different time windows are defined for RT and NRT services respectively due to the various service characteristics. The detailed decision-making algorithm based on time window is explained as follows,

Step-1: If HO user $j \in U_{RT}$, the random delay t_j is generated within the time window [0, T^{evm}]; otherwise, if user $j \in U_{NRT}$, t_j is generated within the time window [T^{evm}, T_1].

Step-2: For RT user $j \in U_{RT}$, the target network is selected as

$$N_{select} = \arg \{ \min {}_{i \in N} -T_{ij} \} \tag{13}$$

For NRT user $j \in U_{NRT}$, the selection principle is formulated as

$$N_{select} = \arg \{ \min_{i \in N} -PLR_{ij} \} \tag{14}$$

It should be assured that $(RB_i - R_j) > 0$ for both RT and NRT users.

Step-3: j^{th} *VHO* user selects target network-AN $_{target}$, and then the selected network updates the available resources as $RB_i^* = RB_i - R_j$. Meanwhile, the network broadcasts this VHO result to other active users with unexpired time window. The frame structures of the most RATs are divided into time slots, and the user selects a available basic resource block in one slot according to the random delay to send handover request. Because the lengths of slot are different for various RANs, it is assumed that δ is the common divisor of various slot lengths. Hence, for RT user, the time window is divided into s time intervals,

$$s = [T/\delta] \tag{15}$$

And the handover user i select one time slot- s_i, to make decision according to the generated random delay t_i. It is assumed that the common divisor δ is 0.25 ms and the user arrival rate λ is 3. It can be observed that the probability is very smaller when several users make decision simultaneously.

4.2 Mobile Controlled – Probabilistic Non-cooperative Approach

Handover latency is an important criterion to evaluate the VHO handover efficiency. In this algorithm, multi-VHO requests are distributed into different target ANs with a predefined probability. In [20] and [21] three types of probability distribution are defined: 1. Conservative type; 2. Risk-preferred type; 3. Trade-off between conservative and risk. For the first one, the values of probabilities for each network change progressively with regard to network performance, while for the risk-preferred type, the user aims to achieve more benefits, so the network with better system performance has much higher probability to be selected. The third one makes tradeoff between the previous two types, the risk preferred type is adopted for the networks whose delay or PLR performance is worse than a threshold, and conservative type is used for the networks with better performance, because these networks are likely to be selected at the same time.

Step-1: MN measures EVM from all available ANs. If the user j is RT user, the MN calculates the transmission delay $T_{ij} = T^{evm}$ according to (10). Let the set AN^{rt}_i denote the candidate network for current RT user, and the elements in AN^{rt}_i are those networks that can provide sufficient available resources. Furthermore, the networks in AN^{rt}_i are sorted by T_{ij}^{evm} in descending order. Supposing the number of networks in AN^{rt}_i is n,

Step-2: predefined probability distribution is given as the probability vector,

$$P = \{P_1, P_2 \dots P_n\} \qquad\qquad \sum_{i=1}^{n} p_i = 1 \qquad\qquad (16)$$

$$P_{cons}(i) = \frac{ln(i+1)}{\sum_{k \in N_i^{RT}} ln(k+1)} \qquad (i = 1,2,3,\dots n) \qquad (17)$$

$$P_{risk-pref}(i) = \frac{exp(i+1)}{\sum_{k \in N_i^{RT}} exp(k+1)} \qquad (i = 1,2,3,\dots n) \qquad (18)$$

$$P_{trade-off}(i) = \begin{cases} \dfrac{p_{risk-pref}(i)}{\sum_{k=1}^{l_o} p_{risk-pref}(k) + \sum_{k=l_o+1}^{n} p_{cons}(k)} & where\ i \in [1, l_o] \\[4mm] \dfrac{p_{cons}(i)}{\sum_{k=1}^{l_o} p_{risk-pref}(k) + \sum_{k=l_o+1}^{n} p_{cons}(k)} & where\ i \in [l_o, n] \end{cases}$$

$$(19)$$

In (19), l_o means the number of networks whose transmission delay or PLR performance is worse than a threshold. In order to provide with different QoS guarantee according to various service characteristics, the third type of probability distribution is adopted for RT users, while the conservative type is given for NRT users.

Step-3: the MT generates a random probability $P \in (0, 1)$, and compares it with the given probability distribution,

Step-4: the current user j selects AN^{rt}_{target} as the target network, and then updates the available resources as $RB^*_i = RB_i - R_j$.

Step-5: For NRT service users the all above 4 steps are repeated and AN^{nrt}_{target} is selected based on packet losses rate as explained in [22].

4.3. Network Assisted Mobile Controlled (NAMC): Cooperative Approach

NAMC approach exploits the merit of cooperative game theory. Following are the important steps to execute NAMC approach.

Step-1: Measure EVM from different neighboring ANs (AN_i).

Step-2: If EVM_i is below $EVM_{threshold}$ then MNs are requested to re-discover the ANs followed by EVM measurements. When EVM_i is above $EVM_{threshold}$ then MN collects attributes of another QoS metric, bandwidth- B_i from neighboring AN_i.

Step-3: Network Cost function is modeled which makes decision based on coordination among VHO requests and multiple networks. In order to guarantee the QoS/QoE requirements at first RT service users are acknowledged and then for NRT service user. Furthermore, matrix D denotes the decision results, which is given as,

$$D = \{d\,(i,j)\}_{mxn} \tag{20}$$

Where d_{ij} indicates that j^{th} RT-user has selected i^{th} AN. $d_{ij} \in \{0, 1\}$, i.e. '1'

for associated with AN_i and '0' for not associated. The aim of decision-making for RT users is to minimize the average transmission of the whole system, which is described as

$$\min_D \frac{i}{m} \sum_{i \in N} \sum_{j \in U_{RT}} T_{ij}^{evm} \tag{21}$$

Based on this objective, the decision-making procedure for RT service is formulated as,

$$\text{Cost} - \text{function} = \min_D \frac{i}{m} \sum_{i \in N} \frac{(D_i R^T)\, T_i^{evm}}{2RB_i^*} \tag{22}$$

$$RB_i^* = RB_i - D_i R^T = RB_i - \sum_{j \in N_{RT}} d_{ij} R_j \tag{23}$$

$$\text{Such that } RB_i^* > 0; \quad d_{ij} \in \{0,1\} \text{ and} \quad \sum_i d_{ij} = 1 \tag{24}$$

Where D_i implies the decision results of network i, and R means the data rate requirements of handover users. The constraints of optimized problem (22) are formulated in (23). The first and the second formula in eq.(23) indicate the admission principle of the proposed handover scheme: the target network should have sufficient available resources for admitted users. The third formula indicates the alternatives of decision result.

Step-4: The cost function gives the decision results to the corresponding networks and then each network updates the available resources and informs the corresponding VHO user for connection initiation. For NRT user, the decision-making procedure is similar with above steps with a difference that the objective for NRT user is to minimize PLR;

$$\min_D \frac{i}{m} \sum_{i \in N} \sum_{j \in U_{NRT}} PLR_{ij} \tag{25}$$

5. Performance Analysis

Proposed VHO algorithm selects the network providing the minimal transmission delay (packet losses rate) and the selection principle for RT and NRT users are formulated in (13) and (14), respectively. It is assumed that there are four available radio access networks in current area as shown in Figure 1, the available resources of each network are denoted by vector RB = {2, 1.5, 2, 3} (Mbps), and the round trip time vector - T_i^{evm} = {100, 200, 300, 400} (ms) describes the corresponding parameters of all available networks. For real-time service, the set of allowable rate is R= {0.1, 0.2, 0.3, 0.4, 0.5} (Mbps) with probability of {0.3,

0.25, 0.2, 0.15, 0.1}, while the same probability distribution is given for the bit rate of non-real-time service as R= {0.5, 0.6, 0.7, 0.8, 0.9} (Mbps). Figure 6 gives the performance comparison of average packet loss rate for non-real time users. Increase in maximum tolerable delay exponentially reduces the PLR and is ~ 0.1 % for 100 ms of delay. Further NAMC proposed model gives relatively low PLR as compared to other models as number of VHO requests increases. Due to resources available at AN, the multiple-requests are dynamically allocated and avoid network congestion.
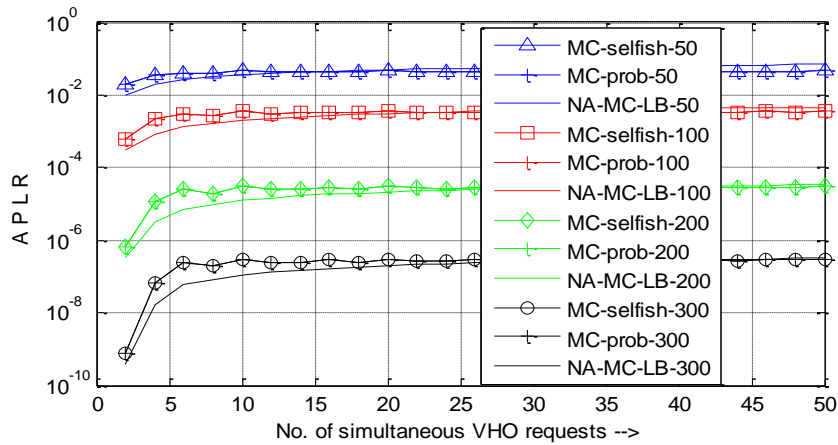

**Figure 6. Avg. Packet Loss Rate for Different T$_{evm}$ – 50/100 ms *etc.***
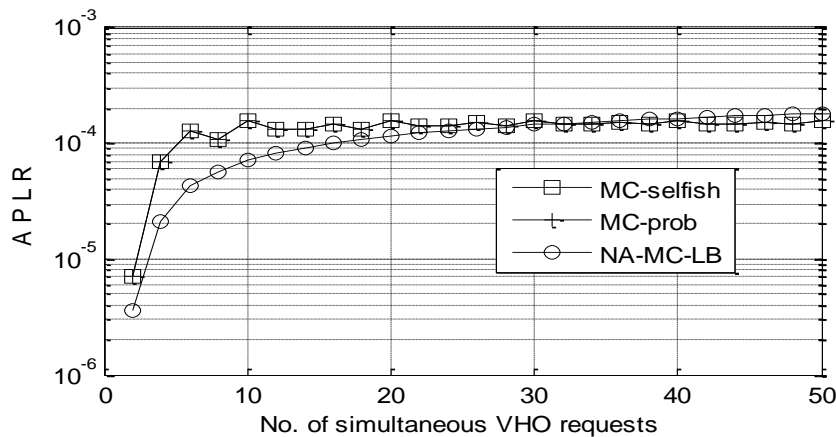
Figure 7. Avg. Packet Loss Rate vs. VHO Requests for NRT Services

In Figure 7, it is shown that proposed NA-MC model gives better PLR and can accommodate up to ~ 35 users with a PLR of 0.01% (accuracy) where as other schemes could accommodate only 6 requests. For NRT application, multimedia services can be seamlessly transferred with a PLR of 0.01 %. Other two methods also give this guaranteed service quality but couldn't accommodate more requests due to non-co-operative approach. Figure 8 gives the performance in terms of average transmission delay for RT services. Delay of proposed model is almost 50% and 70% less when compared with probabilistic and selfish approaches resp. NA-MC model having larger set of RBs can balance the overall network traffic-signaling-load relatively in better manner.
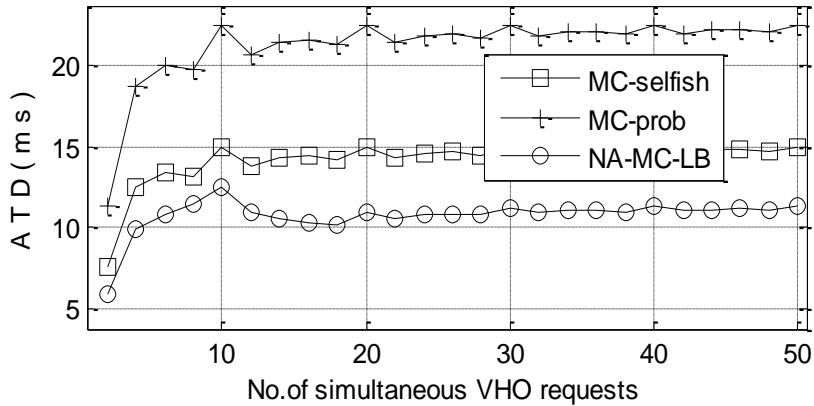
**Figure 8. Avg. Transmission Delay vs. VHO Request for RT Services**

Figure 9 demonstrates the probability that a MN (desiring RT applications) will succeed in availing the RBs from candidate AN. Network (link) availability abruptly reduces to 0.2 % for MC non-co-operative approaches as simultaneous requests exceeds 9. NA-MC exploits the merits of HetNet and due to available RBs the availability rate is greater than 60% for < 20 users and 50 % availability beyond 20 users. Therefore NA-MC is better as compared to other non-cooperative proposed methods. Figure 10 shows the link availability for NRT users being more susceptible to PLR. Mobile controlled probabilistic non-cooperative (MC-prob) approach gives higher availability rate as compared to MC-selfish approach. It is higher because *MC-prob* has larger tolerable delay which allows more users to attempt and succeed. *NA-MC-LB* outperforms other two schemes in terms of higher availability rates and due to ubiquitous heterogeneity the probability of successful guaranteed VHO will always be greater than 50%.
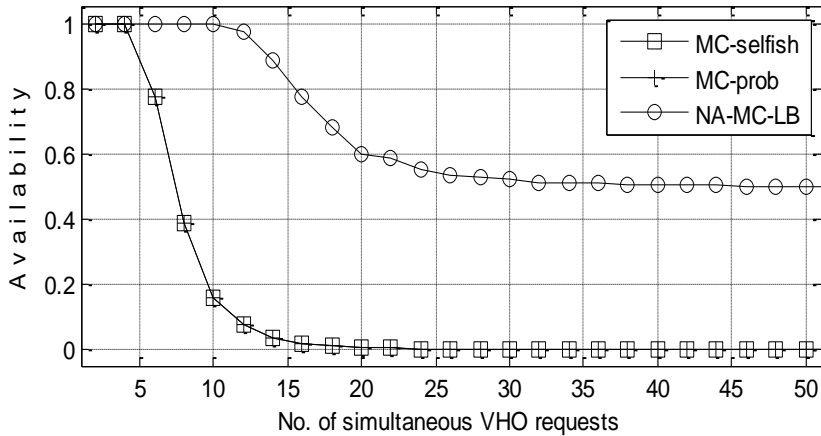
Figure 9. Availability Rate vs. VHO Requests for RT Services
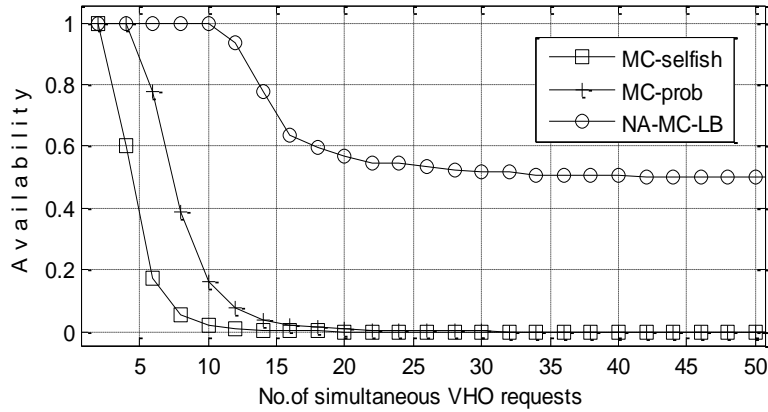
Figure 10. Availability Rate vs. VHO Requests for NRT Services
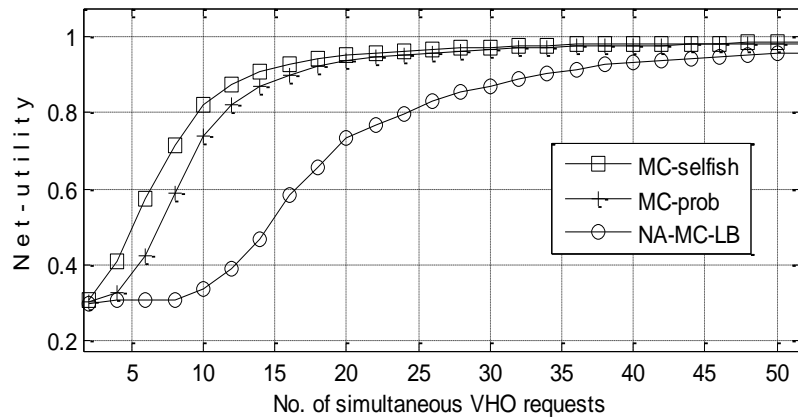
Figure 11. Network Resource Utility vs. VHO Requests

In Figure 11, the global optimized resource utilization of ubiquitous HetNet is shown which offers guaranteed QoE/QoS for diversified multimedia applications. *MC-selfish* and *MC-prob* methods being non-cooperative immediately consumes/reserves the available resources. *NA-MC* being cooperative has sufficient RBs to cater simultaneous VHO requests. Utility is gradually and optimally utilized with the increase in VHO requests. Although beyond 50 simultaneous VHO requests, MNs have very little chance of succeeding in VHO but ubiquitous heterogeneity always gives a scope as there may be an AN which may cater at lower QoS/ QoE approach.

6. Conclusion

Contemporary Vertical Handover (VHO) schemes are basically single user mechanisms and fail to support group mobility due to the incomplete and inaccurate measurements for multimedia applications. Accuracy of spectrum sensing is enhanced by measuring error vector magnitude (EVM) and an optimal VHO procedure is proposed constituting three phases which may terminate after completion of each phase. Proposed algorithms are based on the time window and probability distribution. These are mobile controlled and non-cooperative mechanisms, where as network assisted mobile controlled VHO mechanism co-

operates all ubiquitous VHO-requests. Proposed model investigates and gives guaranteed quality of multimedia services (both real and non-real time) in terms of lower transmission delay, lower packet loss rate, higher network availability rate, maximized resource utility and optimal load balance. Proposed VHO exploits the merits of ubiquitous heterogeneity and provides a global optimization of resources for multimedia services.

7. Future Work

The VHO architecture can be useful for cognitive radio networks, MANETs/ VANETs for spectrum sensing and bandwidth efficiency for diversified multimedia applications in ubiquitous HetNet.

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