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Energy Efficient Vertical Handoff Algorithms – A Review

Priyanka Rani
Dept. of Electronics and Communication Engineering
J.C.D.M. College of Engineering
Sirsa, India

Silki Baghla
Dept. of Electronics and Communication Engineering
J.C.D.M. College of Engineering
Sirsa, India

Dr.Himanshu Monga* (corrosponding author)
Dept. of Electronics and Communication Engineering
J.C.D.M. College of Engineering
Sirsa, India

Abstract: Energy efficiency is one of the major concerns in next generation wireless networks. As the user moves in the heterogeneous environment of different technologies, terminal power consumption increases which results in reduction of battery life time of mobile terminal. The main objective of this paper is to gather the different approaches suggested by various researchers for energy efficient vertical handoff.

Keywords: vertical handoff, energy efficient, Heterogeneous wireless networks, power consumption

I. INTRODUCTION

Next-generation wireless networks relying on heterogeneous technologies allow the users to be connected to various networks. Users may be connected to different radio access technologies like GSM, WIMAX, WLAN, UMTS etc. as no single technology can fulfill users QOS requirements under all conditions. Hence importance of wireless communication is increasing day by day throughout the world due to cellular & broadband technologies. The focus in next generation wireless network is on the selection of best network which provide best services anywhere anytime seamlessly under the principal of always best connected [1]. For seamless mobility &roaming in wireless network service continuity is required. This service continuity is achieved through handoff. Handoff is the process of transferring a ongoing call form one wireless network or access point to another without disconnect the current (ongoing call). Depending on the type of network technologies involved, handoff can be classified as either horizontal or vertical [2].Horizontal handoff involves terminal devices to change cell within the same type of network to maintain service continuity (eg. CDMA to CDMA).while vertical handoff is an asymmetric process in which handoff occurs between different base station belongs to different network (eg. CDMA to WLAN). Figure 1 show the process of vertical handoff and horizontal handoff .Hence terminal power consumption is continuously increasing has resulted in an ever decreasing battery lifetime. Additionally due to battery problem of mobile devices, energy efficiency is one of the important subtopic of vertical handoff process.

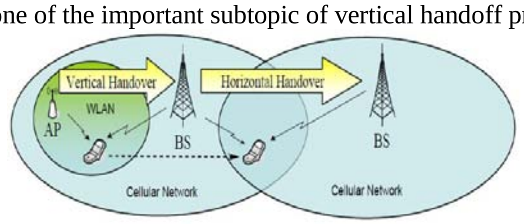

Fig.1 Process of horizontal &vertical handoff [3]

The rest of the paper is organized as: Section II presents the process of vertical handoff. Section III describes the overview of energy efficient techniques in heterogeneous network. Section IV concludes the paper.

II. PROCESS OF VERTICAL HANDOFF

Vertical handover process consist of three main phases are information gathering, decision making and handoff execution (as shown in fig.2)

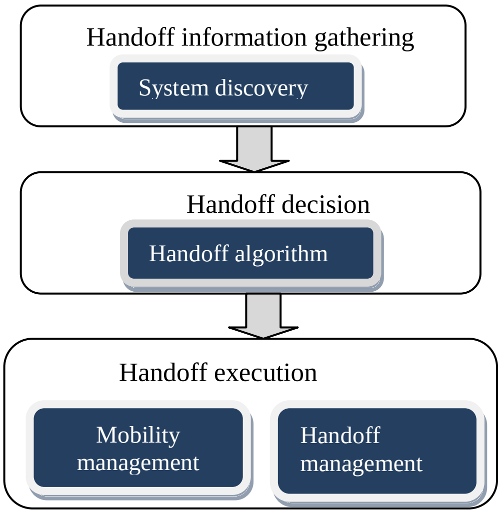

Fig.2 Three phases of handoff

A. Handoff Initiation

In this phase information to be collected about the network from different link layer, application layer & transport layer provide the information such as RSS ,bandwidth Power, cost, jitter, user preferences, throughput etc

B. Handoff Decision Making

In this step, mobile device decides whether the connection to be continued with current network or to be switched over to another one. The decision may depend on various parameters including the type of the application (e.g. conversational, streaming, interactive, background), minimum bandwidth, and delay required by the application, access cost, receiving power RSS, latency of switching process, and the user's preferences [4].

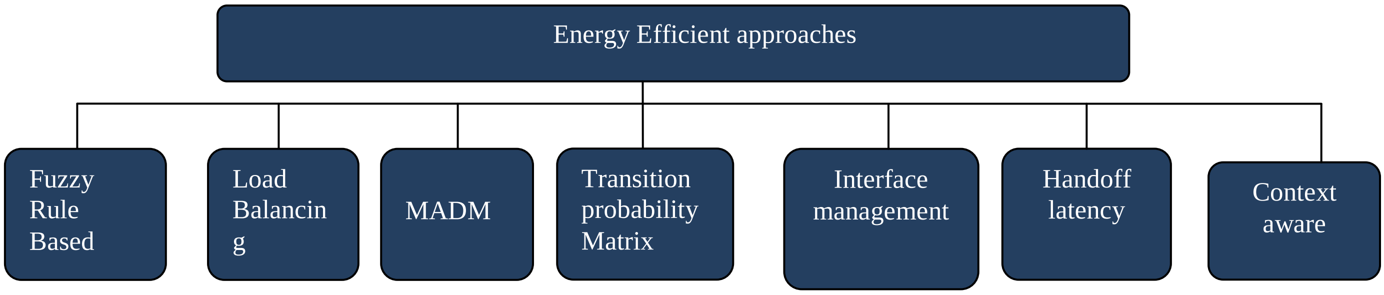

Fig.3 Energy efficient approaches

C. Handoff Execution

In this phase, existing connections need to be re-routed to the new network in a seamless manner. Once the information is collected in phase 1 and processed in phase 2 by selecting the network candidate, the execution phase will trigger a network binding update.This phase is concerned with control, security, session and mobility etc. [5].

In every phase of handoff, energy is also consumed whether the device is in connected mode or in idle state. Thus energy efficient vertical handoff is need of present era of communication in wireless networks.

III. RELATED WORK

The various approaches for energy efficient vertical handoff suggested by researchers can be broadly categorized as:

A. Fuzzy rule based algorithm

Efficient vertical handoff algorithms are required to maintain the acceptable level of quality and seamless connectivity in heterogeneous network. Various researchers proposed fuzzy rule based algorithm for meeting the requirements of heterogeneous networks.

A fuzzy logic handoff decision scheme was proposed in [6] for improving energy efficiency of Femtocell base station and also deal with the imprecise information of some criteria and user preference. For femto cell base stations IDLE mode has been introduced which reduced energy consumption to37.5% approximately. While in [7] using the same scheme average number of vertical handoffs & ping pong effect was reduced by 13.3% and 15.9% by considering six parameters and data base rule set in vertical handoff decision algorithm. In order to improve quality of service the end-point service availability (ESA) was increased by 16.57%. Seamless and optimized VHO algorithm was proposed in [8] for normalization of parameters. The proposed algorithm calculates the Performance Evaluation Value (PEVs) of the available networks and also compares the parameters for handover decision making based on the highest PEV available.

B. Load balancing

Due to heterogeneous environment, number of macro/femto cells increases so large amount of energy is wasted when a femto base station is active in the low network load. Hence load balancing of macro and femto cells is very necessary for reducing energy consumption. Various researchers proposed efficient load-aware vertical handoff (VHO) algorithm for Heterogeneous networks.

A load balancing technique was proposed in [9] for network selection between WLAN and CDMA network. For load balancing handoff triggering criterion uses both the RSS and distance information, and a network selection method which uses context information such as the dropping probability, blocking probability , GOS (grade of service), and number of handoff attempts. Same technique is proposed in [10] which eliminate the unnecessary handoff while balancing the load of the macro and femto cells at minimum energy consumption. The performance of the proposed algorithm is analyzed using Continuous Time Markov Chain (CTMC) Model. By using this algorithm, balanced threshold level of the received signal strength (RSS) is determined for providing equal load distribution of the mobile users to the macro and femto BSs. The balanced threshold level is evaluated based upon the distant location of the femto cells for small scaled networks. In [11] an efficient load-aware (ELA) vertical handoff (VHO) algorithm was proposed for heterogeneous network for providing system load information from the neighboring cells. The proposed algorithm can reduce the computational complexity during VHO procedure eliminating the non-necessary handoff possibilities. The ELA algorithm can also effectively tackle the off-loading procedure for the BS/APs with relatively light traffic loads.

C. MADM

Multiple attribute decision making includes various methods like: AHP, GRA, MEW, TOPSIS etc. are used for network selection and reducing energy consumption based on multiple attributes.

A network selection algorithm was proposed in [12] considering power consumption in hybrid wireless networks for vertical handover. This algorithm is composed of the power consumption prediction algorithm and the final network selection (AHP&GRA) algorithm. The power consumption prediction algorithm estimates the expected lifetime of the mobile station based on the current battery level, traffic class and power consumption for each network interface card of the MS. If the expected lifetime of the mobile station in a certain network is not long enough compared the handover delay, this particular network will be removed from the candidate network list (CNL). Simulation result shows that power consumption prediction algorithm can prevent unnecessary handover when the battery level is very low and final network selection algorithm can select the optimal network in CNL by user preference.

An algorithm for reducing handoff matrix was proposed in [13] which combine techniques of two MADM methods ANP&GRA is used. Analytic network process (ANP) method is used to find the weights of the available networks, and the grey relational analysis (GRA) method is used to rank the alternatives. From this method it can be deduce that due to correlation between the three criteria (packet delay, packet jitter and packet loss) the optimized network selection algorithm eliminates packet jitter and packet loss.

In[14] a novel method of utility-based fuzzy TOPSIS method is presented for energy efficient network selection that takes into account user preferences, network conditions, QOS and energy consumption requirements in order to select the optimal network which achieves the best balance between performance and energy consumption. In [15] fuzzy rule based (FRB) and TOPSIS technique was presented that integrates the mechanisms of energy efficiency by considering power consumption at mobile station, and various QOS parameters.

Authors in [16] [17] and [18] also used MADM method for network selection.

D. Transition probability matrix

Transition probability matrices have been developed by Markov process for both data and voice communication in cellular and WLAN. Markov process is used for reducing unnecessary handoff and energy consumption in heterogeneous network.

Transition probability was introduced in [19] for both data and voice communication in cellular and WLAN. Simulation result shows that energy of mobile station varies with variation in data rates. As data rate increases, more and more energy is required by the MS to communicate with the AP. While in [20] same process is used to select a network during handoff by considering delay and cost as its basic parameters. This algorithm can be used to reduce call dropping probability and satisfies user's requirements during vertical handoff.

Markov Decision Process (MDP) based Vertical handoff decision algorithm was proposed in [21] for the heterogeneous wireless networks. It combined MDP model with AHP method for maximizing the expected total reward during the transmission. Simulation scenarios show that the expected total reward of the proposed MDP-based algorithm is higher than that of other three algorithms, MDP for single MT, SAW, RSS based algorithm.

E. Interface Management for Energy Efficiency

Energy consumption can be managed at interface level of mobile terminal. Various researchers proposed interface selection algorithm for energy-efficient vertical handoff**.**

An *WISE* (Wise Interface Selection) algorithm was proposed in [22]which selects the energy-efficient network interface, by taking into consideration not only the energy consumption of each NIC(WLAN&3G), but also the network throughput. *WISE* utilizes *VDC*, which balances the network traffic load and takes the decision to perform vertical handoff. The simulation results showed that energy consumption & throughput can be improved through *WISE*, which dynamically selects which energy efficient network

In [23], CDMA and WLAN are considered for energy optimization mechanism in vertical handoff. For this purpose algorithm is designed where the power consumption rates of the two popular NICs provide efficient power management in MTs without network degradation. According to algorithm, multi-standard mobile terminals (MMT) selects the most energy-efficient interface for the current communication state (transmit, receive or idle) while it simultaneously switches-off the idle interface.

Energy Efficiency is investigated for TCP transmission over a WIMAX network in [24] under different MAC configurations, wireless and wired traffic conditions. Simulation results indicated that TCP transmission with non real time polling service (NRTPS) reduces energy consumption by 35% compared with that in the BE when the WIMAX network is under a heavy workload. Same energy efficient technique is proposed in [25] for Mobile Terminal Interfaces Management in modern mobile terminal. The results attained through simulations shows that the proposed method can reduce 30% mobile terminal energy consumption depending on the considered threshold distance. It can be even higher when a large amount of different RAT interfaces are integrated in the mobile terminal.

F. Handoff latency

Handover of calls between two base stations is encountered frequently and the delay can occur during the process of handover. This delay is known as handover latency. An energy efficient handoff should have low handover latency & lesser number of handovers along with optimum network selection.

In [26] an effective and novel vertical handoff decision scheme is introduced. It considers bandwidth, dropping probability and cost parameters as metrics of the network selection function. It places the calculation of the network quality at the target network (TVNs) side instead of the mobile terminal side. Simulation results showed that it has lower level of processing delay and a higher level of throughput. MADM methods will also used for network selection by considering low handoff latency. In [27] Five MADM algorithms (SAW, MEW, TOPSIS, AHP and GRA) were proposed for network selection by comprising six candidate networks as UMTS, WLAN and WIMAX (two of each kind). Simulation results show that MEW algorithm possesses least handover latency among all the MADM algorithms but network selection is not accurate as desired by user. On the other hand TOPSIS exhibits large handover latency along with desired network selection. Thus there should be a compromise between these two main requirements of handover. While in [28] various handoff delay reducing techniques were presented like Handoff using Neighbor Graph (NG), Deuce- Based Fast Handoff scheme, Handoff with Null Dwell time Scheme, Pre-active scanning scheme& Rotational Multiple Channel Allocation Scheme and Neighbor list proactive (NLP) based handoff schemes for reduction of handoff latency.

G. Context Aware Energy Efficient

Context-aware solution was proposed in[29] that considers both users and services requirements for efficient vertical handoff. It uses contextual information that was collected during the information gathering step and processed to be used as the input data for the network selection stage. The

same approach is used in [30] for supporting energy centric vertical handoff decision making. The proposed framework consist of three auxiliary module Real-Time Monitoring Module (RTMM) Context Fusion Module (CFM), Network Discovery Module (NDM),and one main module vertical handover decision engine(VDE).Real-Time Monitoring Module (RTMM) monitors a energy efficient parameter which are related to mobile device and information about the access point. The CFM integrates the derived cross layer measurement raw data to auxiliary VHO contexts, while the NDM provides a list of available point of attachments (POA) to VDE. The VHO decision engine has two functions: The first function is management of network discovery by triggering NDM if battery level is low & signal strength decreases under a threshold in the currently connected network. The second function of VDE is the evaluation of the candidate POAs with the context gathered from CFM including the currently connected network characteristics such as energy profile, QOS parameter.
Table1 shows the various approaches for energy efficient vertical handoff.

IV. CONCLUSION

Energy efficient vertical handoff techniques are required for providing service continuity in heterogeneous networks. In this work, various approaches to energy efficient vertical handoff have been compiled. The literature reviewed shows that multiple attribute decision making algorithm based methods are able to provide optimum network selection in large number of quality of service attributes. Energy consumption is one of the attribute among them. These techniques have gained attention regarding energy efficient vertical handoff. Other techniques also serve the purpose and can be combined with MADM based methods.

Table 1: Energy efficient VHO approaches

Approaches for energy efficient vertical handoff	
FUZZY Logic	[6] , [7] ,[8]
Load balancing	[9], [10],[11]
MADM	[12],[13],[14],[15],[16],[17],[18]
Transition probability matrix	[19],[20],[21]
Interface management	[22],[23],[24],[25]
Handoff latency	[26],[27],[28]
Context aware	[29],[30]

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