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Multi-Criteria Handoff Decision Algorithms In Wireless Networks

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Abstract: *In recent years the technology in the field of wireless networks has been advanced. The mobile users are demanding access to the wireless networks at anytime and anywhere. To ensure the service continuity and to maintain the promising QoS, the decision regarding handoff is to be taken appropriately. The most common criteria for handoff is received signal strength which is not sufficient in advanced networks. Thus, this paper reviews the multi-criteria based handoff decision algorithms in wireless networks. Different techniques for multi-criteria handover are also discussed.*
Keywords: *Wireless networks, Handoff, Decision, MADM;*

I. Introduction

The wireless networks [1] that use wireless data connections for connecting network nodes, by which homes, telecommunications networks and enterprise (business) installations avoid the costly process of introducing cables into a building, or as a connection between various equipment locations. Table 1 is illustrates the types of wireless networks with their range, application and standards. There are two types of Handoffs (HO) [2]: Horizontal and Vertical Handoff.

Mobility management [3] comprises of location management and handoff management. The previous one tracks the mobile for successful information delivery while the handoff management maintains active connections for roaming mobile terminals. In cellular telecommunications, the term handoff or handoff refers to the process of transferring an ongoing call or data session from one channel connected to the core network to another channel. In satellite communications it is the process of transferring satellite control responsibility from one earth station to another without loss or interruption of service.

Table 1. Types of wireless networks

Type	Range	Applications	Standards
Personal area network (PAN)	Within reach of a person	Cable replacement for peripherals	Bluetooth, Zig Bee, NFC
Local area network (LAN)	Within a building or campus	Wireless extension of wired network	IEEE 802.11 (Wi-Fi)
Metropolitan area network (MAN)	Within a city	Wireless inter-network connectivity	IEEE 802.15 (Wi-MAX)
Wide area network (WAN)	Worldwide	Wireless network access	Cellular (UMTS, LTE, etc.)

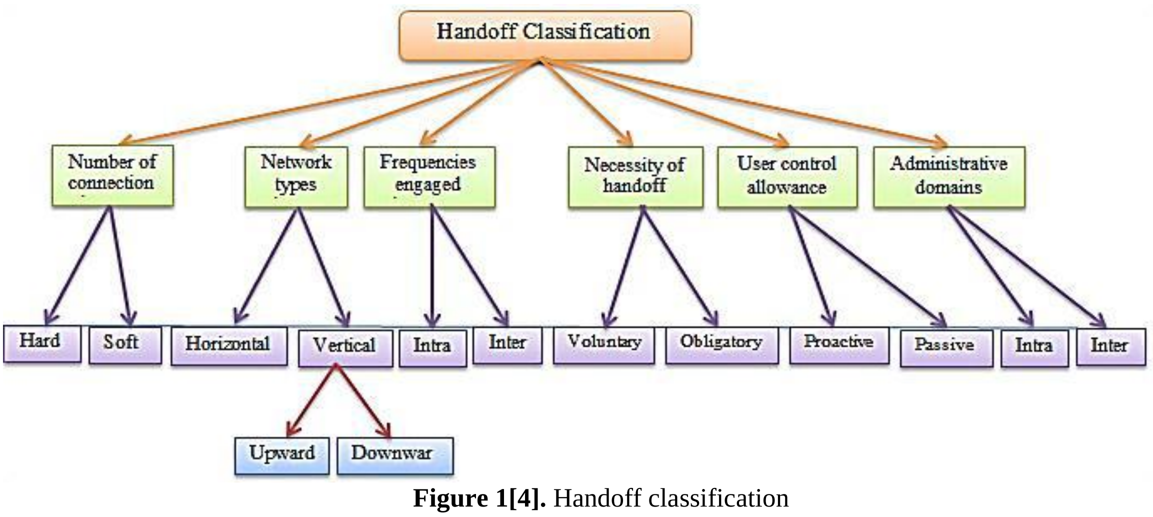

Figure 1[4]. Handoff classification

Figure 1 shows the HO classification on the basis of different parameters. Three major steps of vertical handoff management [5] are: 1.Handoff Initiation 2. Handoff Decision 3. Handoff Execution. The focus of the present work will be on Handoff Decision techniques as it provides the best system and privilege time for handoff.

There are different types of algorithms for vertical Handoff [6] including the following: Cost function based algorithm (in this type of algorithm, a cost function is calculated for each candidate network [7] and different weights are assigned to distinctive input metrics depending upon the system conditions and user preferences), Context aware algorithm (in this type of algorithm, the information, are related to the mobile host, network and other contextual parameters for intelligent decision making [5]. This information may include capacity, location, user preferences, network QoS, coverage, QoS requirements, and service type e.g. real-time, interactive or streaming traffic.), Threshold Based algorithm (in this type of algorithm, at any time, the server maintains the IDs of the k last reported MNs and the k thresholds that define the distance ranges where objects can move without causing a result change. [8]), Pattern recognition algorithm (this type of algorithm depend on the type of label output, on whether learning is supervised or unsupervised, and on whether the algorithm is statistical or non-statistical in nature), Position Aware algorithm, Received Signal Strength (RSS) based algorithm (in this type of algorithm, RSS is the primary handoff decision criteria. These algorithms use the RSS of the current network and the candidate network [9]), Artificial Intelligence based algorithm.

Each of the above mentioned algorithms has its benefits and limitations. The artificial intelligence, such as neural and fuzzy based algorithms is proving to be very promising to improve the HO efficiency in wireless networks. The term “Neuro-Fuzzy” [10] can be associated with hybrid systems which act on two distinct subprograms: a neural network is utilized in the first subprogram (e.g. in signal processing) and a fuzzy logic system is utilized in the second subprogram (e.g. in reasoning task). Neural networks, concentrate on the structure of the human brain, i.e., on the “Hardware” emulating the basic functions, whereas fuzzy logic systems concentrate on “software”, emulating fuzzy and symbolic reasoning. Some of the Vertical Handoff Decision (VHD) criteria/parameters are directly related to the distance between the mobile node and its point of attachment [11]. It is used as a primary decision criteria in most of the existing handoff decision algorithms), System Association time : is the time span that a mobile node stays connected with a current connection and is particularly important for VHD algorithms on the grounds that heterogeneous systems typically have diverse sizes of network [12], Available Bandwidth (BW) : is a measure of the average number of bits transmitted over a channel, Power utilization :If a mobile node’s battery is low, then it would be desirable to switch to network, which would have low power requirements [13], Money related expenses, Security, User preferences : is client's personal inclination towards an access network might lead to the choice of one kind of network over the other kind. The algorithm based on multi-criteria are able to reduce the handoff delay and service disruption time, which finally decrease the packet lost and increase throughput during handoff. Fuzzy logic and Artificial Neural Networks [10] (ANNs) are extensively used in literature to perform vertical handoff decisions in order to select the best access network for a Mobile Station (MS). The application of these complicated algorithms is necessitated by the complexity of vertical handoff decisions and dynamic conditions of wireless networks.

In this literature, we provide a complete overview of the recent VHO decision making mechanisms using different techniques. This survey then analyzes and discussed. The remainder of this work is organized as follows. Section 2 presents different types of Handoff decision algorithms for heterogeneous wireless networking, including Universal Mobile Telecommunications System (UMTS), Worldwide Interoperability for Microwave Access (Wi-MAX), Wireless Fidelity (Wi-Fi), Long Term Evolution (LTE) and Femtocell. Section 3 describes the target network selection based on Multi-Attribute Decision Making (MADM) Technique for Heterogeneous Wireless Networks (HWN). Section 4 describes the target network selection based on Neuro-Fuzzy algorithm for wireless networking. Section 5 provides an overview of research gap of different algorithm is used for target network selection for heterogeneous wireless networking followed by scope for the future work. Section 7 concludes the paper.

II. Handoff Decision Algorithms for networks (UMTS, Wi-MAX, Wi-Fi, LTE)

In this section different handoff decision algorithms are introduced to reduce unwanted number of handoffs and to improve Quality of Service (QoS) for different networks like UMTS, Wi-MAX, Wi-Fi, LTE. The author in [14] proposed a Vertical Handoff (VHO) algorithm for heterogeneous network architecture which integrate both cellular network and Wireless Local Area Network (WLAN). In this work, VHO decisions are taken based on parameter coverage and traffic load of WLAN and algorithm ensures better performance in target selection. Some authors like [15], [16], [17] & [18] make use of Markov Decision Process (MDP) in order to optimize the HO performance. In [15], the RSS based single attribute HO decision is considered. The choice of preferred network is determined according to connection lifetime with the help of MDP. The awarded total reward is maximized and number of handcuffs are minimized. Another MDP based cell selection method using Value Iteration Algorithm (VIA) is proposed [16] in which dynamic channel load and link quality have been considered to reduce the number of handoff and signaling overhead. The vertical handoff decision algorithm in [17] provides support for multiple types of services (video, voice, file transfer protocol) with different priorities. By modeling vertical handoff process as an MDP, a new reward function is introduced which consists of both QoS profit and Handoff cost. So this algorithm decreases the number of handoffs by 15% to 22% as compared to the existing algorithm like Simple Additive Weighting (SAW) VHDA. In most of the research works, major challenge is the handoff across various HWN as well as reduction of call drop probability. One of the solution of the above mentioned problem is described in [18] for the improvement of end-to-end QoS supporting high data rates, real time transmission over a wide area and enabling users to specify their personal preferences using MDP. This method uses delay as its basic parameter to select a network during handoffs. The simulation shows that algorithm reduces call drop probability and satisfies user's requirements. Some authors have proposed QoS based handoff scheme [19,20] for Wi-MAX/WLAN networks. According to [19] whenever MS is out of range of all Access Points (AP)/Base Stations (BS), then it can communicate through any other station, which are in range based on ad-hoc network technology and provides communication service to users. A central method of handoff management is proposed in [20] based on cloud technology and fuzzy logic by which QoS has been increased in mobile station based on efficient network and the optimal procedure of intelligent vertical Handoff. Now, for providing service to a Mobile Node (MN) by choosing an appropriate network, a Modified Optimization (M-OPTG) [21] VHO or Horizontal Handoff (HHO) algorithm is presented. It provides a better performance on the basis of battery life time, load balancing, call dropping probability and minimizing the number of handoff by considering the velocity of MN for the real time scenario using network simulator.

In addition to reducing the number of handoffs, delay is another parameter which is to be reduced [22]. The number of handoffs and decision delay are estimated and compared for different value of standard deviation of shadow fading and velocity of Mobile Terminal (MT) of interest. The RSS with dwell timer based VHO algorithm gives the best performance among all VHO algorithm in Third Generation (3G) and WLAN networks. In previous papers, slow moving vehicle is considered while in order to improve the handoff performance in high speed railway [23], a Location Based Handoff Algorithm (LBHA) in LTE network is proposed for high speed, mobility scenario, which is expected to support the subject's mobility at a speed of up to 500km/h and reduces the probability of unnecessary handoff. A realistic performance evaluation framework for packet loss based VH triggering algorithm for voice over WLAN/Cellular media proposed in [24] by which utility of the framework is increased.

The authors in [25] proposed the seamless approach to perform vertical and horizontal handoff for reducing the probability of call blocking and dropping during the handoff process and also reduced the unnecessary handoff in networks. This scheme is adding some parameters like cost, coverage area, available BW, velocity of MN along with RSS for making handoff decision.

In all the above mentioned papers, different criteria have been used, but which parameters are good and responsible for a fruitful handoff process is an open issue. So, to find out the widely used parameters for fruitful handoff process, different parameters are identified and studied based on the path traversed by the HO decision process [26]. This work concluded that most widely used input parameters for decision process are RSS, BW, speed, cost, direction, Signal to Interference Noise Ratio (SINR) for achieving seamless mobility. To reduce the ping pong affect and minimize the number of HOs, the authors in [27] propose a vertical handoff decision strategy using History Based Communication Graph Algorithm (HBCGA). This work highlighted the fact that user behavior is unpredictable. The authors in [28] proposed a user oriented handoff decision strategy that considered its preferences to enhance mobility experience. In this work, utility-based decision scheme is a single criterion utility function applied to each decision criterion and an adaptive multi-criteria utility function that aggregates decision criteria according to user preferences. According to the results, this approach satisfies principally users' requirements and outperforms the concave utility, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and RSS based methods.

Once the decision regarding handoff is finalized the next challenge is to select the most appropriate technique network for handoff.

III. Target network selection based on MADM Techniques

In this section, researchers adopted MADM techniques in order to select the most suitable target network for HO. The commonly used MADM [29,30] techniques are: TOPSIS [30]: the chosen candidate network is the one which is the closest to ideal solution and the farthest from the worst case solution, SAW [31]: the overall score of a candidate network is determined by the weighted sum of all the attribute values., Multiplicative Exponent Weighting (MEW), Weighted Product Model (WPM) [32], Grey Relational Analysis (GRA) [33]: is then used to rank the candidate networks and selects the one with the highest ranking. The vertical handoff decision with multiple attribute is a complex problem, MDP [34]. In order to implement the above mentioned techniques for handoff, an entity named as Media Independent Handoff (MIH) [35] is to be used. The Media-independent framework is a scalable and efficient method of addressing inter-technology handoffs. With a common platform in place to address handoffs, each access technology requires only a single extension to ensure interoperability with all other access technologies. This is the approach embraced by the IEEE 802.21 standard, which defines a common set of MIH services that interact with the higher layers of the protocol stack. The authors in [36] proposed architecture for the best network selection and resource management in heterogeneous environment based on IEEE 802.21 standard for handoff initiation and preparation. The information collection, monitoring and resource reservation are based on an MIH algorithm with input criteria of speed of MT, QoS, type of service, security level and cost. The authors in [37] compared different techniques of VHO decision in HWN based on various MADM techniques and concluded that TOPSIS is better decision maker as compared to SAW. In continuation with above the authors in [38] compared SAW with another decision maker WPM and found WPM as better than SAW. To deal with the false handoff indications, an optimizing handoff triggering technique based on Global Positioning System (GPS), Location Service server (LSS), is proposed to name as GRA [39]. This work has considered the context of energy consumption for scanning frequency and failed handoff, packet loss ratio, handoff delay for simulation. Some authors like [40, 41] also compared multi-criteria vertical handoff algorithms for performance evaluation in HWN. To improve network performance in terms of number of handoff, network balance and average blocking probability, the author in [40] compared multi-criteria (equal, mobile and network priority) vertical handoff decision algorithms. The number of handoff is decreased by 84.60%, while network balance is improved by 20.23% and average blocking probability improved by 20.23% when compared to conventional method (single criteria RSS based). The authors in [41] compared handoff decision algorithms named as MEW, SAW and TOPSIS in terms of end-to-end delay and packet loss using two available networks WLAN and Wi-max using NS-3. Simulation results show that MEW, SAW and TOPSIS perform differently to four traffic classes in term of Packet Loss and Delay. The authors in [42] proposed an algorithm based on Reinforcement Learning (RL) and MDP for the selection of best network.

The authors in [43] addressed the handoff decision and target network selection issue in 3rd Generation Partnership Project (3 GPP) LTE-A networks, in order to prevent congestion state by considering network capacity and load of metrics. To maintain more dynamism and autonomy, the target Radio Access Technology (RAT) selection scheme is devised by integration of MIH protocol. Simulation results show that this algorithm improved load balance index and also maintain a lower rate of VHO block, which enhances network performance.

A performance evaluation analysis of MADM methods (GRA, MEW, TOPSIS, SAW) for network selection using real user data is conducted on Google Nexus one android mobile device in [44] to have a tradeoff between energy efficiency and user perceived quality level. Simulation results show that MEW finds best energy quality trade-off for users among all MADM solution. Some authors like [45,46,47] make use of Analytic Hierarchy Process (AHP) to improve data rate, to reduce the ping-pong effect and to select largest Potential Contribution Ratio (PCR).

In [45], the authors proposed cross layer based dynamic handoff algorithm for handoff requirement factor estimation and target network selection and eliminated unnecessary handoff and reduced the signaling overhead and service interruption. In this work, TOPSIS combined with Fuzzy AHP is used to assign priority to parameters responsible for handoff decision. The proposed mechanism can easily respond to expected changes in network condition by tuning the weights used for implementing TOPSIS. Simulation results show that the performance of Handoff algorithm is improved up to 43%, 35% and 17% in terms of data rate, delay and security in comparison of conventional algorithm.

Table 2 Performance studies

Ref	MADM method	Criteria	Networks	Conclusion
[35]	GRA,TOPSIS, SAW,MEW, WPM	Packet Loss, Handoff Delay	LTE, Wi-Fi, Wi-MAX	GRA is the best among all.
[37]	MEW, SAW, TOPSIS, AHP	Packet loss, Delay, BW, Jitter, BER	Wi-MAX, WLAN, Wi-Wi	TOPSIS is the best among all.
[44]	GRA, MEW, TOPSIS, SAW	Energy efficiency, QoS	WLAN,UMTS	MEW finds better QoS than GRA, TOPSIS, SAW
[49]	SAW, MEW, TOPSIS, GRA	Bandwidth, packet delay, packet loss, monetary cost Throughput	WLAN, UMTS, Wi-MAX	SAW and TOPSIS are suitable for voice connections resulting in low packet delay, while GRA, MEW are suitable for data connections obtaining high throughput
[50]	TOPSIS, GRA	Cost per byte, bandwidth, security, packet delay, packet Loss	UMTS, WLAN, Wi-MAX	TOPSIS, GRA has the highest criticality index for all traffic classes
[51]	SAW, MEW,	Loss rate, delay,	UMTS,	TOPSIS,GRA, and SAW perform better than

	TOPSIS, GRA	Bandwidth	GPRS, WLAN	MEW for the best effort.GRA, SAW and TOPSIS have Similar performance
[52]	SAW, MEW, TOPSIS, ELECTRE, GRA	Available bandwidth, total bandwidth, packet delay, throughput	WLAN, UMTS	GRA, MEW,and ELECTRE are suitable for data connections obtaining high throughput while SAW and TOPSIS are suitable for voice connections resulting in low packet delay

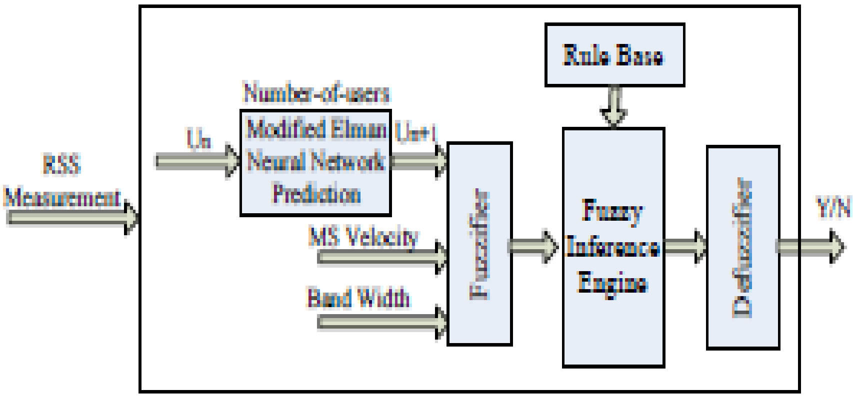

Fig:2 [53] Adaptive Multi- Criteria Vertical Handoff decision algorithm

Another research work in [46], proposed Fuzzy Logic Processing (FLP) combined with AHP for UMTS and Wi-MAX overlay networks. In FLP section, dynamic network parameters including RSS and BW are exploited to evaluate the User satisfaction (US) by fuzzy inference. In AHP section, a decision matrix is constructed using the parameters of service cost, battery consumption, and network delay and user preference. Finally, the decision is made according to the weighted value of the US and AHP for different traffic type. The approach effectively mitigated the ping-pong effect as well as terminal power consumption.

Another methodology termed as the bankruptcy game is combined with AHP in [47] which AHP takes the responsibility of evaluating weights of multiple decision criteria, which depends more on the consideration from the user side. On the other hand, the bankruptcy game is mainly used to assess the potentials of available candidate networks. Finally, the combination of AHP and the bankruptcy game evaluates the PCR of each candidate network and the network with the largest PCR is selected. A dynamic programming method (Knapsack- TOPSIS method) is given in [48] that divide the network into zone to get better performance in terms of QoS.

In the table 2, the performance evaluation is done on the basis of different parameters and for different wireless networks. In this section appropriate network selection is done on the basis of different algorithms for different wireless networks. With the help of comparison, the best technique is also decided to select the target network.

The next section is based on research regarding target network selection for handoff on the basis of Neuro-Fuzzy algorithm.

IV. Target network selection using Neuro-Fuzzy based algorithm

In this section, the target network selection using the Neuro-Fuzzy based algorithm is discussed. In highly integrated wireless environment, the selection of a network that can fulfill end-users service requests while keeping their overall satisfaction at a high level is vital. The wrong selection can lead to undesirable conditions such as unsatisfied users, weak QoS, network congestions, dropped and/or blocked calls, and wastage of valuable network resources. Traditional schemes perform the handoff necessity estimation and trigger the network selection process based on a single metric such as RSS. These schemes are not efficient enough, as they do not take into consideration the traffic characteristics, user preferences, network conditions and other important system metrics.

Some algorithms utilize the multi-criteria based on Fuzzy logic like Fuzzy Inference System (FIS), Hybrid Fuzzy Genetic Algorithm (HFGA), Fuzzy Set Representation (FSR), Fuzzy VIKOR (FVIKOR), Fuzzy Logic Controllers (FLC) and some are based on Neural Network that is Modified Elman Neural Network (MENN), Adaptive Neuro-Fuzzy Inference System (ANFIS). The concept of fuzzy logic can further be utilized to make the decision algorithm, adaptive [53,54]. In [53], the authors proposed an Adaptive Multi- Criteria Vertical Handoff (AMVHO) decision algorithm which uses FIS and MENN for WLAN-UMTS with BW and velocity as input parameters. Simulation results show that AMVHO is effective in taking the accurate HO decision in terms of BER, Delay, SNR and QoS. In [54], the authors' proposed fuzzy logic and Adaptive

Network Fuzzy Inference System (ANFIS) based vertical HO decision algorithms to reduce the number of HO. For HWN that consists of GSM/GPRS, Wi-Fi, UMTS and WI-Max technologies with the parameter data rate, monetary cost and RSSI information are processed as input of the developmentally fuzzy based system. After simulation, it is found that ANFIS reduced number of HO compared to SAW and the purely fuzzy based algorithm.The AMVHO algorithm

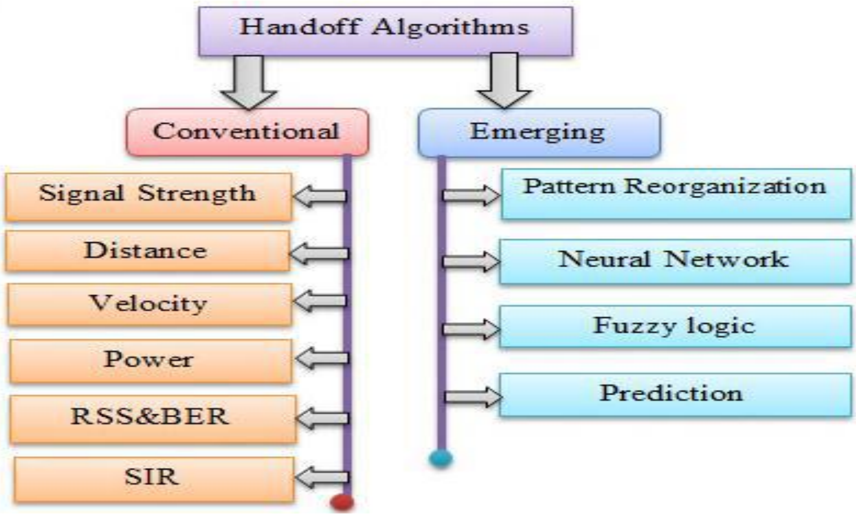

Figure: 3 [4] Handoff algorithm

consists of a MENN predictor and FIS as shown in Fig. 2. RSS measurement indicates the current radio link quality, and acts as a pretreatment that helps to decide, whether to trigger the decision process or not.

A similar approach exploiting the concept of Neuro and fuzzy is employed for High Altitude Platform (HAP) in [4]. This is based on Radial Basis Function Network (RBFN) to enhance QoS in HAP which provides services to users getting weak signal. The signals can be insufficient from the terrestrial system or can be covered area influenced by shadowing with RSS. The direction of MS, HAP position, traffic intensity, steerable antenna, the elevation angle of HAP and delay are input parameters of neural networks. Simulation results show that HO rate and dropping rate decreases as compared with other traditional method. Also HO rate increases if traffic intensity increases as well as HO rate decreases when mean arrival time increases. Conventional handoff algorithms are described as shown in Fig. 3 for various types of handoff algorithm. To raise the above discussed HO algorithm, to the next level, a highly efficient technique named as Genetic Algorithm (GA) is used in [55]. This cost effective approach is named as HFGA-VHA so as to provide a great potential and to perform different applications. A fuzzy logic based optimization approach for tuning fuzzy membership function is developed. Fig.4 explains the fundamental component of the ANN, an artificial neuron, Radial basis function (RBF) to the neural network for making handoff decisions. The authors in [56] proposed a VHD criteria based on input parameters of predicted RSS, BW and user preference. The results of HO decision are calculated by fuzzy logic based VHDA which is used to select the most appropriate network for MN. These selected MN is handled over to another nearby BS. Simulation results show that VHDA can make accurate HO decision and improved the performance of network.

The authors in [57] proposed a Grey theory based prediction algorithm which is used to get the predicted RSS, that can tell when to start a HO and reduces the ping-pong effect. This fuzzy theory based Fuzzy Quantization Decision Algorithm (FQDA) is applied to each of the candidate network and final optimized handoff decision can be made based on resulted Quantization Decision Value (QDV). Previous work is based on the Grey theory for the reduction of ping pong and new approach is based on predictive RSS and reduced fuzzy system using Rough set theory [58]. To reduce the ping –pong effect as well as call dropping probability, a predictive RSS with the dwell time scenario is proposed in which sugeno type of Fuzzy inference engine is used to achieve computational efficiency and can be applied in real time application.

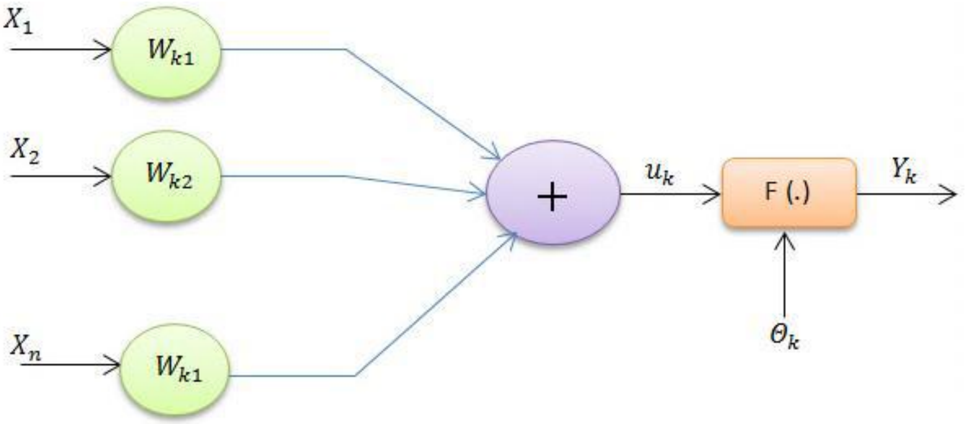

Figure:4 [4]. Model of artificial neuron

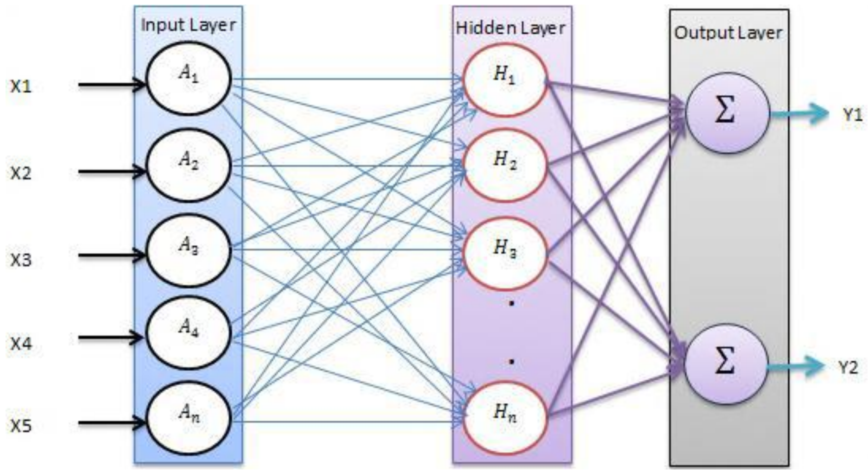

Figure:5 [4]. RBF neural network

The RBFN consists of three different layers, an input layer, a hidden layer, and an output layer as shown in Fig. 5. The input layer acts as an entry point for the input vector; no processing takes place in the input layer. The hidden layer consists of several Gaussian functions that constitute arbitrary basis functions (called RBF); these basis functions expand the input pattern into the hidden layer space. This transformation from the input space to the hidden layer space is nonlinear due to nonlinear radial-basis functions. The output layer linearly combines the hidden layer responses to produce an output pattern. The multiplicative weighted utility function is also proposed [59,60]. In [59], the authors provide the optimization between QoS, cost and energy consumption and function is verified using Cobb Douglar based user satisfaction degree. The service is offered by the selected network and for the calculation of the overall rating of the network the aggregation of multi-criteria are performed through the use of the FSR TOPSIS method in [60]. The authors in [61] presented the use of fuzzy logic concepts to design an adaptive multi-criteria VHDA which is cost effective and highly useful.

The authors in [62] presented a novel multi-attribute VHA for HWN which achieves seamless mobility while maximizing end-users satisfaction. To estimate the necessity of handoff and to select the target network basically two modules are designed. These modules utilize parallel FLC with reduced rule-set in combination with a network ranking algorithm. This is based on FVIKOR with the help of requested traffic class, the speed of the MS, network loading and users cost and security preferences. All the above methods are based on Fuzzy theory, but this new method is a neural network based VHDA Levenberg- Marquardt algorithm [63] which is capable of switching between Wi-Fi, GSM-GPRS, UMTS, Wi-MAX technology and to combine the parameters i.e. data rate, monetary cost, RSSI in order to initiate HO process. After comparison with classical method (MADM, SAW) and other VHA it is observed that this neural based proposed algorithm will reduce the maximum number of HO and handoff latency. An algorithm is based on Neuro-Fuzzy named as ANFIS [64] which is used to provide not only flexibility to LTE for initial deployment, but also the adaptive capability to optimize the efficiency of the handoff algorithm with minimal human interference. For the need of better mobility management LTE has introduced Self Organizing Networks (SON) in order to provide autonomous control over the management of the network.

V. Research Gap

Though many researchers have done a lot of work on handoff decision methods, yet some research gap is still left which need to be filled in order to provide best services to mobile users. For instance, the authors in [4,38] considered multi-criteria parameters in terms of number of handoff, network balance, average blocking probability, BW, velocity as input, however, they ignored the impact of traffic load, latency, QoS, RSS, security while taking a decision about hands-off.

The authors in [23] improve the handoff in high-speed railway a speed of upto 500 km/h and speed above the given limit is a limitation of this research. In [24] algorithm is proposed only for 3G topology and author, considered a slow moving vehicle in the proposed model. So, 4G and high speed vehicle can also be used in next research. The authors in [45] ignored the impact of end-to-end latency, signaling load. In [48], security is the open issue.

The authors in [15] show that future wireless communication system will consist of various kinds of WAN, and seamless vertical HO between different network is a challenging problem in HWN.

In paper [16] the work can be extended in different ways that to design heuristics evaluate over a more complex network to derive procedural guidelines and examine the effectiveness of these research techniques in heterogeneous networks. When the research is for selection of the best technique like (TOPSIS, MADM, SAW, MEW, WPM, GRA, MDP, then multi-criteria method can be combined with other VHO methods such as cost function and fuzzy logic. This combination may improve the network performance.

In [40] other performance metrics like end-to-end latency, signaling load can be explored and in HO execution using mobility protocols like FMIPV6 is also an open issue.

In [48], security, support during HO through authentication schemes can be investigated for a vertical decision making process and this work can be extended to LTE system. Also the work can be implemented along with coupling architecture to measure the performance results.

VI. Conclusion

In this paper, the multi-criteria based handoff decision algorithms have been discussed in detail. The researchers have considered a number of parameters in order to take a decision regarding network selection for handoff. Different algorithms have their contributions and limitations. Various MADM techniques based algorithms like TOPSIS, MEW, SAW and GRA, are also mentioned and analyzed in this paper. The research gap is found and then future scope is also given.

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