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PSO-NF based Vertical Handoff Decision for Ubiquitous Heterogeneous Wireless Network(UHWN)

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***Abstract*—In this paper, Hybrid of Particle Swarm Optimization (PSO) and Neuro-Fuzzy (NF) has been proposed for improving Vertical Hand-off (VHO) decision for the Ubiquitous Heterogeneous Wireless Network (UHWN). The mobile users have made VHO decision based on data-rate, dwelling time and service type, residue energy and network connection time. To reduce the computational complexity, the pre-decision of VHO is made based on preference of user and number of non-occupied channel. The main aim is the improvement of Quality of Service (QoS) of link and reduction of hand-off frequency. This method is able to reduce call blocking probability, hand-off latency and hand-off call dropping probability, improve the throughput and also balance the load of radio access technologies. The execution of the proposed system has been performed using NS 2 simulator. The numerical results of the proposed algorithm outperforms the state-of-the-art method.**

Keywords*—*PSO; Neuro-Fuzzy; RSSI; VHO; QoS

I. Introduction

Heterogeneous Wireless Network (HWN) is a gathering of different types of wireless devices. And these devices are always accessible and available at whatever time at any place. Wireless communication devices consists of various pervasive devices such as mobiles, GPS units, cordless telephones, wireless computer parts, ZigBee technology and satellite television etc. When these wireless devices are able to omnipresent high speed data access at any time and at any place is called Ubiquitous heterogeneous wireless network (UHWN). For anytime and anywhere connectivity in UHWN, integration of various network access technologies is obligatory to support high speed data rate, mobility without call interruption, reducing call dropping probability.

Cellular telecommunication system is divided into various small cells. Small cells are good for frequency reuse and coverage. So, when users move from one place to another, UE becomes connected to various cells of various technologies. To continue the connection, hand-off occurs. Otherwise, call becomes dropped and user becomes dissatisfied.

Hand-off confers to the process of the transition of a data connection or active call in a non-interrupted way. The transitions occurs from one base station to another base station which may be geographically apart. Generally, two types of hand-offs are widely used. One type of them horizontal hand-offs, is used in a homogeneous wireless network. Hand-off triggers within the same network. When mobile terminal moves within the same wireless network technologies, horizontal hand-off focuses on reducing numbers of calls failed. Horizontal hand-off handling capability exists in today's network technologies. In another hand, Hand-off triggering among different access technologies is called vertical hand-off (VHO). Here, the mobile terminal moves into different networks where different access technologies are used. In order to maintain higher throughput within different collocated networks, VHO is indispensable.

So, it becomes a vital issue to enhance the overall performance of seamless connectivity in a HWN. To correctly take the decision, balance the load, maintain energy efficiency and QoS, efficiently handle resource utilization, provide security, reduce cost, VHO algorithm should be carefully maintained. Complexity becomes higher to consider all the factors. The best candidate network selection is the main complexity from the pervasive networks based on the numerous criteria. Choosing best candidate network depends on various performance metrics such as ubiquitous mobility with coverage, delaying in the time of handover, handover frequency , handover shortage probability, throughput and combinations of these parameters.

Considering these issues, a hybrid PSO-NF based VHO decision algorithm has been introduced. For tuning the parameters of a fuzzy inference system (FIS), NF uses neural network. NF controller parameters are: data rate (DR), network connection time (NCT), service type (ST), Energy consumption (EC) and dwelling time (DT) . To train the NF system, hybrid back propagation method and least mean square algorithm is used. On the other hand, PSO is used to select initial parameters intelligently. It increases convergence speed and makes a decision in a short period time. This method is able to reduce call dropping probability, maintain quality of service, balance load, lessen hand-off call blocking probability and handle the energy more efficiently. Initial step is used to avoid ping pong effect. Initial step decision depends on two parameters: user preference and number of free channel. This also avoids algorithm complexity.

Remainder paper is well organized as below: section III represents PSO-FNN based VHO algorithm, section IV represents the Simulation and Analysis and section V finally draws

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the conclusion.

II. Related Works

The choice of VHO algorithm is random. Many of VHO algorithm can give disputable results. To get indisputable results, it is important to choose the method very cautiously. Various approaches has been proposed for improving for VHO decision [1]–[3], [6]–[19], [21], [22], [24]. The decision parameters can be received signal strength (RSS), bandwidth, network connection time, handover latency, power consumption, monnetary cost, security, bit error rate (BER) and signal to interference ratio (SIR), user preferences and many more [4], [5]. In another hand, dynamic programming or artificial intelligece, for example, neural nework(NN) or fuzzy logic, pattern recognition, or genetic algorithm (GA) is considered more effective in case of vertical hand-off decision prediction [2], [6], [10], [12], [15], [19], [21], [22]. As fuzzy logic (FL) systems and NN classifiers are non-linear and capable of generalization. And GA has better uncertainty and imprecision tolerance, good learning ability and adaptability. But problem occur when the networks needs to scalable. For the initial parameter and weight optimization in expert systems, PSO is used effectively [14]–[16], [18].

RSS based VHO algorithm increases handover delay, as it takes sample RSS points and make average of it [3], [9]. Problem also occurs when close RSSI among candidate network technologies are found. In that case, number of hand-offs becomes higher and throughput becomes lower. Packet delay and throughput becomes lower [9]. VHO based on SINR provides better throughput because it directly related with signal to interference plus noise ratio [8]. Considering only bandwidth, the handover occurrence becomes higher due to shadowing and fading. Problems with data rate, energy efficiency and handover failure probability exists. Also call dropping probability becomes higher [8]. To keep low the number of handover occurrence, to get higher throughput and take user preferences into consideration, cost function based VHO is introduced [11], [13]. But problem occurs in the calculation of security and interference levels and network resource wastage [11], [13].

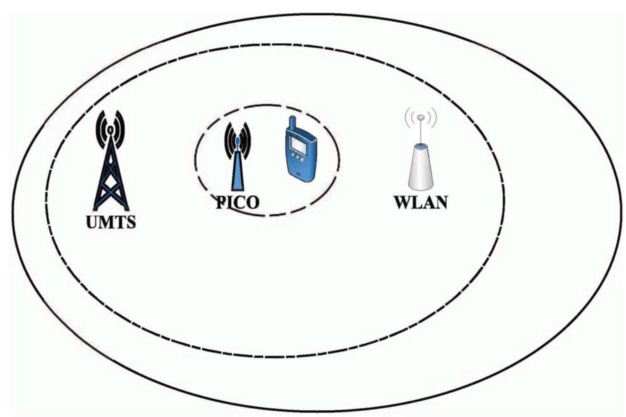
Fuzzy logic and ANN are more suitable than traditional techniques because of their cognitive uncertainty, learning mechanism, adaptation capability, fault tolerance capability, parallelism and generalization capability. It is impossible to draw out rules from NN. Integration of special information about problem is ambiguous into the NN to make easy learning [6]. User Preferences, energy efficiency are not considered in the paper. So, quality of service are not ensured [21].

There need a trade-off of handover delay time and system load in fuzzy based system [2]. Bad network condition and variation of user requirement needs variable weights but three input parameter weight is fixed [4]. Load balancing, users preferences and service quality are not taken into consideration [12]. Load conditions, allocation of resources, energy efficiency, higher data rate acquisition is unreasonable in [10]. However, in fuzzy logic based VHO algorithm, knowledge acquisition is difficult. Expert knowledge is needed to set rules. And another limitation is fuzzy logic works worst with higher number of inputs.

Balancing load, HCBP is successfully performed in [12], [15], [19]. Bandwidth and received signal strength are used as the parameters of FNN controller. And PSO is used for initial parameter learning. But User preferences, Data rate and energy efficiency are not taken into consideration and consent for lower computational cost is illogical [15].Genetic Algorithm is used to set the beginning weights and threshold for neural network [12], [19]. User preferences, Energy efficiency is not taken into consideration [12]. In [19], genetic algorithm and fuzzy algorithm correctly determines whether a handoff is necessary or not. User Preferences, Load balancing are not considered in the paper. Cost function is used to select best network for handover and particle swarm optimization for optimizing weight in real time is proposed in [14]. Energy are not handled efficiently, also the user preferences are not reflected. Grey model along with fuzzy inference rules to predict the received signal is proposed in [17]. Then the prediction is fine-tuned by PSO which optimizes better than self-tuning algorithm. But energy efficiency, user preference and call blocking probability are not taken into consideration [17]. Do not consider energy efficiency, data rate and user preferences. Handling data fusion is also a major issue [16]. Another dynamic method is proposed in [18]. But this method is not energy efficient.

III. PSO-NF based VHO Algorithm

A HWN environment are designed consisting of LTE(4G), UMTS(3G), GSM(2G), WLAN and picocell. An UE receives signal from these collocated networks considers many factors to connect to a specific network. The hand-off scenario based on our proposed PSO-NF based VHO algorithm is shown in 1.



three parts of this paper is : intial screen-out step, PSO-NF controller and finally performing hand-off decision. First, User Entity (UE) predicts network according to RSSI.

Then initial screen-out method selects some candidate networks and removes some networks according to user preference and channel utilization. The main flow of our proposed method is shown in 2.

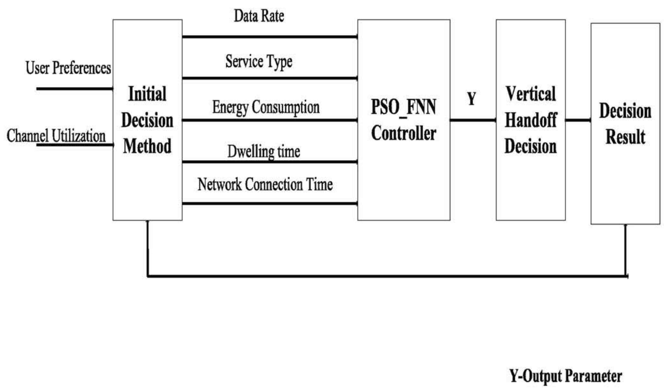


Fig. 2. Flowchart of Vertical Hand-off Decision Algorithm

The parameters data rate, network connection time, service type, energy consumption and available energy and the time a device spends in a cell without moving are feed into hybrid controller. HO decision finally is performed based on output parameter Y. PSO is used with the FNN controller to optimize the weight of the it.

B. Initial Screen-out Method

According to RSSI, user entity discovers various radio access technologies first. Then, some networks are removed according to the number of non-occupied channel and priority of networks. If user entity belong to the network that is preferred by users, then no hand-off occurs. But if current network is not user preference list, then hand-off is occured to the network which are preferred by any users with low mobility nature of user entity. In case of no user preference and low mobility, hand-off decision is performed by the NF controller. But with user preference or without user preference, if any entity travels back and forth in a high speed, no hand-off will occur.

For avoiding ping-pong effect, initial decision process is performed before hand-off decision process and ensure the user satisfaction. If no hand-off is needed, then the flow directly go to the decision step. This reduces hand-off decision complexity in large extent. So, this is enable to guarantee the QoS and to cut-down the number of candidate networks primarily. The user entity with busy channel and no user priority, is removed from the candidate networks.

C. NF Vertical Hand-off Controller

FL and NN are two different tools in constructing intelligent systems. NN mainly deals with raw data where as fuzzy logic are good at reasoning. With the help of parallel calculation and also learning capabilities, fuzzy systems along with ANN can perform human-like knowledge representation. Combining the advantages of two intelligent systems, fuzzy neural network (FNN) is used to acquire excellent performance. FNN still suffers convergence problem and it is necessary to adjust the weights more intelligently. PSO, a good optimization method is used to set initial parameters. And for increasing the convergence speed.

1) Structure of NF: Fuzzy logic has the ability to represent human decision making capability in IF-THEN forms. Crisp input are fuzzified into membership function which values lie between 0 and 1. Then through output membership function, de-fuzzification is performed. Here a five layer NF is considered to implement the proposed system. It comprises the input, input membership, fuzzy rule, output membership and finally output. For training NF, back propagation along with Least Mean Squares(LMS) algorithms are used [23]. The proposed structure for NF is shown in 3 [20].

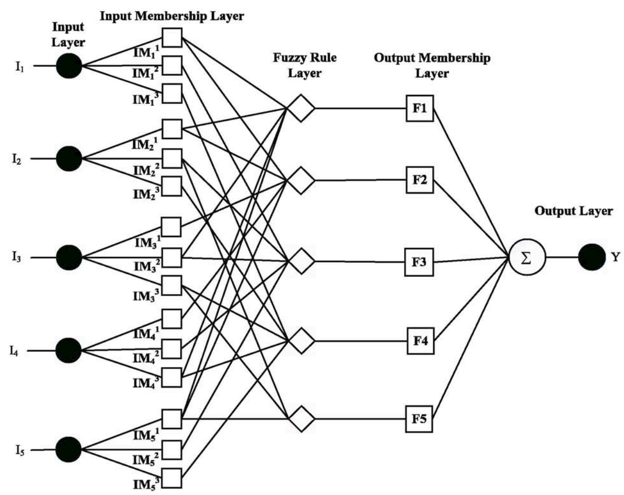


Fig. 3. Structure of NF system. I: Input, IM: Input Membership Function, Y: Output.

NF structure considers input as I_c, output as Y.

$$I_c = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \end{bmatrix} = \begin{bmatrix} DR \\ NCT \\ ST \\ EC \\ DT \end{bmatrix}$$

Where, DR = Data Rate, NCT = Network Connection Time, ST = Service Type, DT = Dwelling Time, EC=Energy Consumption.

For membership function, we adopt Gussian function. Input membership layer is responsible for transforming the crisp input into linguistic level. The output of this layer can be calculated as:

$$Y^2_{cd}(I_c) = exp(-\Sigma^r_{c=1}[(I_c - m_{cd})^2/s^2_{cd})]) \quad (1)$$

$d = 1, 2, 3, ..., x$. Here, x is the number of neurons in membership layer. m_{cd} and s_{cd} are the average and standard deviation of Gaussian function. Fuzzification process receives crisp input and determines the degree of the fuzzy set. Here, fuzzy set (L, M, H), represents Low, Medium and High which is applicable for all input variables from input layer.

The membership functions are calculated from fuzzy rules. The linguistic variable in the input are $IM_c^1 = Low$, $IM_c^2 = Medium$, $IM_c^3 = High$. The output of each rule, F_c, is calculated as:

$$F_c = \beta_{c1}I_1 + \beta_{c2}I_2 + \beta_{c3}I_3 + \beta_{c4}I_4 + \beta_{c5}I_5 + \beta_{c6} \quad (2)$$

where β_{cd} is the parameters of input d.

Final output of the FNN controller is calculated by:

$$Y = \Sigma_{c=1}^{L}[\frac{\Pi_{d=1}^{L} IM_c^d(I_c)(F_c)}{\Sigma_{c=1}^{R}(\Pi_{d=1}^{l} IM_c^d(I_c)}] \quad (3)$$

Here, L is linguistic variables number and R is the rules number.

2) Particle Swarm Optimization: Initial parameters of NF is an important matter. This parameter and threshold is optimized by PSO.

PSO belongs to swarm intelligence. This technique performs stochastic optimization . Particles velocity and positions is continuously updated in the search space. According to the fitness value of each particle, personal best and global best value is also updated.

The change of velocity is followed by the mathematical equation given below:

$$s_{mn}(e+1) = ws_{mn}(e) + a_1 * r_{1n}[pbest_{mn}(e) - p_{mn}(e)] + a_2 * r_{2n}(e)[gbest_n(e) - p_{mn}(e)] \quad (4)$$

And The change of any particles position is expressed as

$$p_{mn}(e+1) = p_{mn}(e) + s_{mn}(e+1) \quad (5)$$

Where,
$p_m(e)$ presents current location of the mth particle at time e.
$p_m(e+1)$ represents location of mth particle at time $e+1$.
$s_m(e+1)$ represents velocity of mth particle at time $e+1$.
$s_{mn}(e)$ is the inertia component.
$a_1 * r_{1n}(e)[pbest_{mn}(e) - p_{mn}(e)]$ is the cognitive component.
$a_2 * r_{2n}(e)[gbest_{mn}(e) - p_{mn}(e)]$ is the social component.
The a_1 and a_2 is positive cognitive coefficients whose value close to 2 and affects the step size of particle toward its pbest and gbest.

Step by step of PSO:

- First task is to initialize the position and velocities of a group of particles. This can be set arbitrarily. Initialize the speed $s_{mn}(0) = 0$.
- Particles fitness value is calculated by the equation (6).

  $$f = C|r_m - p_m| \quad (6)$$

  where, C is the positive constraint; r_m is the realistic value. p_m is the expected value.
- *pbest* is the best value in the observation of personal m and *gbest* is the global best. These values are initially determined.
- The positions and velocities are updated continuously according to (4) and (5). Calculate the fitness value of each. Update fitness value of current position of personal and global comparing with initial.
- Checking the stopping condition, declare new gbest value is the optimal best value if terminated. if not, then repeat the calculation.
- Lastly, Initial parameters of NF is declared from the co-ordinates of gbest.

Algorithm 1: Proposed Vertical Hand-off Decision Algorithm

```
Input: user_pref, channel_utilization
begin
    if (current_network ≠ user_pref)
    begin
        if (user_pref == no && channel_utilization == low)
        begin
            Input I_c from available networks, N.
            Train FNN by hybrid back propagation
            and least mean square algorithm.
            For (Available FNN Layer)
                Calculate output for each layer using
                (1)-(2)-(3).
                Return output Y.
            End For
            Select network, N ← Y : Y ∈ NFC.
            Perform hanfoff for network N.
        end
        elseif (user_pref == yes && channel_utilization
        == low)
            Perform hanfoff for network, N ← user_pref.
        else
            no handaff.
    end
    else
        no handoff.
end
```

D. VHO Decision

The hand-off decision is decided from the value of Y of NF controller. If the value Y is between 0 and 0.20, handoff will be performed to UMTS, If the value of Y is between 0.20 and 0.40, hand-off will be performed to GSM, If the value of Y is between 0.40 and 0.60, hand-off will be performed to Pico cell, if the value of Y is between 0.60 and 0.80, hand-off will be performed to LTE and If the value of Y is between 0.80 and 1.00, hand-off will be performed to WLAN. Markov chain process is able to calculate probability of transition from one state to another. Probability is calculated as:

$$p_{i,j} = p(s_{t+1} = i | s_t = j) \quad (7)$$

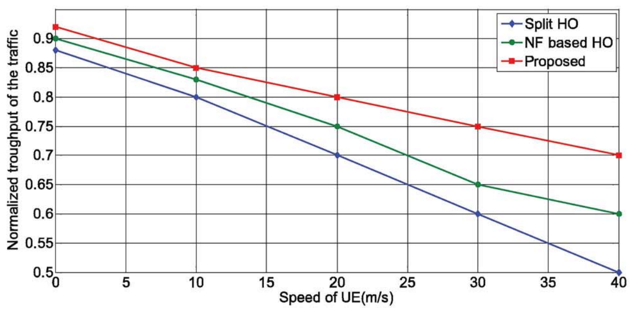


Fig. 4. Normalized throughput of traffic during handoff

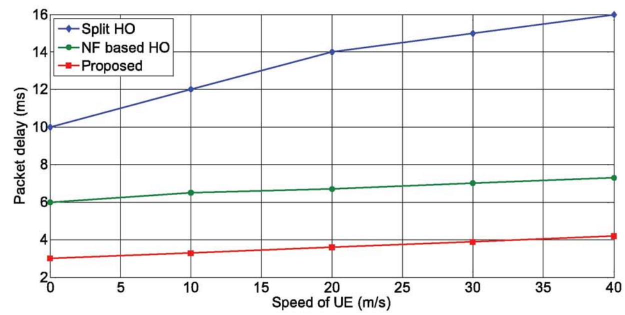


Fig. 5. Packet delay as a function of speed of UE

Here $i, j \epsilon s$ and s is the state space. GSM, picocell, LTE, UMTS and WLAN forms the state space for this case.

IV. Simulation and Results

This section includes the simulation setup and results. The simulation has been done in NS2 considering mobility of UEs. In the model we have considered LTE (4G), UMTS(3G), GSM(2G), WLAN and Pico networks.

A. Simulation Parameters

The simulation parameters are ordered in the Table 1.

TABLE I. Simple table

Parameters	Value
UMTS cell range (m)	1000
WLAN 802.11 cell range (m)	50-100
Pico cell range (m)	0-30
LTE cell range (m)	800
GSM cell range (m)	1500
Propagation model	Rayleigh
Antenna	Omni-directional
AP transmit power	0.02 to 0.06mW
Application Traffic for UE	Cluster based routing
Simulation duration (seconds)	500
Data rate	200Kb, 1Mbps, 4Mbps
Applications type	H.261, MPEG-4, HDTV
Packet Size (byte)	1000
WLAN 802.11 cell range (m)	512, 800, 1024

B. Simulation Result

When a UE resides in pico or WLAN coverage, the average RSSI is higher and better throughput can be achieved. Here we have compared our results with the split HO [26] and NF based HO [25]. Figure 4 shows the normalized throughput of traffic during handoff. It has been found that the normalized throughput of the proposed VHO algorithm outperform compared to NF based HO and split HO techniques.

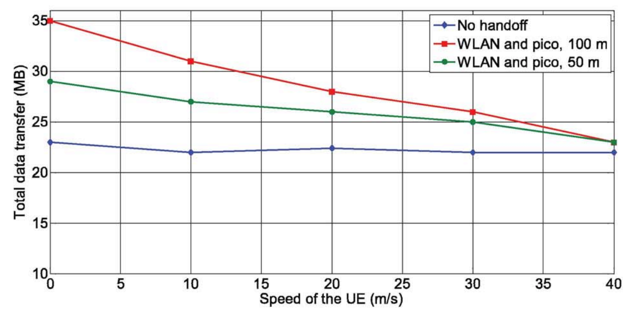


Fig. 6. Effect of UE speed on aggregated data rate

Figure 5 shows the effect of UE's speed on the packet delay. It has been found that the packet delay is higher for the split HO compared to NF based HO and proposed VHO. The packet delay is less for the proposed HO algorithm. It is due to the fact that the proposed algorithm converged very fast compared to its counter parts.

Figure 6 illustrated the affects of UE's speed on total data rate. In this case, our proposed approach outperforms. It is because our approach reduces the HO frequencies compared to NF based HO and Split HO algorithms.

V. Conclusion

Firstly, network discovery is performed based on received signal strength. To avoid complexity, user preference and channel utilization is used as initial decision step. This also increases user satisfaction and avoid unnecessary hand-off. Then NF based VHO algorithm for the ubiquitous heterogeneous wireless network has been proposed to choose best network accurately. The parameters of VHO decision method based on service type, data-rate, time of staying in a cell without transition, network connection time and residue energy. The evaluation of the proposed method has been performed using NS 2 simulator. The result proves that the proposed method outperform the state-of-the-art method. This work can be extended by comparing the algorithm with other machine learning approaches and statistical methods.

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