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Fuzzy Neural Networks in Vertical Handover Technology for Next Generation In Wireless Networks

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Abstract: Wireless communications has evoked a revolution in the communications industry, with the potential to provide high-speed high-quality information exchange. Currently, there are several wireless networks deployed around the world like cellular networks, metropolitan area networks, wireless local area networks, heterogeneous wireless networks and personal area networks etc. Wireless network devices are equipped with multiple access technologies like UMTS and Wireless LAN. The combination of all these networks is usually called the next generation wireless networks. New state-of-the-art mobile terminals will allow users to free movement and also enable them to switch connections among different access networks. This process named vertical handover imposes important technical challenges for the emerging next generation wireless networks. This paper explores the concept of vertical handover and its classification. It also highlights the differences with traditional handover. The following section of the paper focuses on implementing fuzzy logic to solve several routing protocols and handover problems efficiently in wireless networks.

Keywords: vertical handover, vertical handoff, handover decision algorithm, Next Generation wireless networks, horizontal handover, WiMAX, UMTS, 3G, Fuzzy logic, BFNN, neuro fuzzy systems.

I. INTRODUCTION

The future mobile networks will most likely be based on a packet-switched architecture. With such architecture, the 3G mobile networks can easily be extended by other IP based wireless access technologies like Wireless Local Area Network or Worldwide interoperability for Microwave Access (WiMAX). The design and purpose of these various wireless networks are completely different. We already have the ongoing Universal Mobile Telecommunications System (UMTS) as a representative of 3G cellular networks which provides wide-area coverage with high mobility and a comparatively low bandwidth.

On the other hand, several technologies like Wireless LAN provide a lower coverage area but offer a high bandwidth. Combining these technologies creates a ubiquitous wireless network with local hotspots to supply the user with high speed services. Various approaches are available to combine Wireless LAN and UMTS and how to perform a handover between these technologies. Almost every approach is based on Mobile IP and its extensions. The actual trend is to integrate complementary wireless technologies with overlapping coverage, to provide the expected ubiquitous coverage and to achieve the Always Best Connected (ABC) concept.

The ABC concept allows the user to use the best available access network and device at any point in time. In the next generation wireless networks, the emerging mobile devices will be equipped with multiple network interfaces to access different networks. These new mobile devices will provide the user with great flexibility for network access and connectivity but it will also generate the challenging problem of mobility support among different networks. This problem will be taken care by the revolution in wireless networks which is referred to as handoff or handover. Through this users will be able to continue their connections without any disruption when they move from one network to another.

Now, with the emerging mix of next generation wireless networks being deployed, the handover has become more complicated in nature and therefore not easy to manage. So, the handover process among networks using different technologies is defined as vertical handover. The term *vertical* refers to overlapping wireless networks and their hierarchical and asymmetric relationship. The objective of this paper is to introduce the vertical handover in next generation wireless networks.

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II. LITERATURE REVIEW

In the context of cellular networks a handover is defined as the mechanism by which an ongoing connection is transferred from one base station to another. The base stations are the infrastructure that is deployed by the cellular operator to facilitate service in a geographic area. If we consider that both base stations use the same access technology, we can say that homogeneous wireless networks perform horizontal handover.

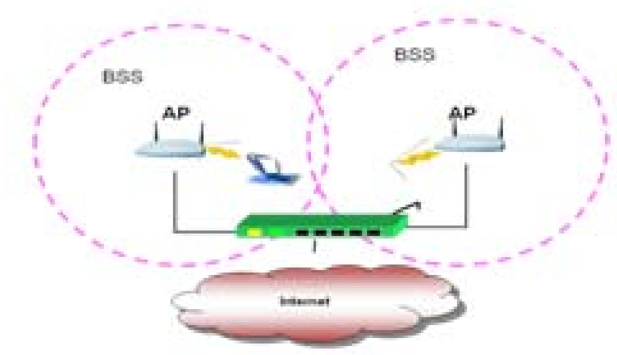

Figure 1. Horizontal Handover

On the other hand, if we consider heterogeneous wireless networks, and access points (APs) from WLANs using a different one, we can say that a vertical handover is the mechanism by which an ongoing connection is transferred from one base station to an access points and vice versa.

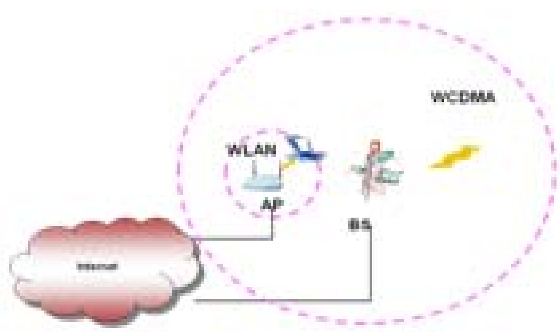

Figure 2. Vertical Handover

A. Problem analysis: The vertical mobility paradigm deserves research attention from many perspectives. During the past decade both telecommunication and Internet technologies have been in a phase of rapid development. Still, the mobile Internet evolution has taken many important steps towards providing better quality wireless data services to a wide audience. In cellular networks, evolution for the first three generations contributed to growing data rates and enhanced communication capabilities, achieving its current peak only recently in the third generation (3G) mobile networks and handsets.

At the same time wireless local area networks have achieved enormous popularity in providing wireless broadband connection in public, enterprise and residential environments. Combining the two fore mentioned wireless technologies has attracted researchers now since about a decade, but there still remain issues to study. The next evolutionary steps after the third generation aim to provide extended mobility with optimized data rates and services. Nomadic users have more flexibility when using multiservice networks that provide services such as seamless connection to the Internet via heterogeneous networks, advanced spatial location and navigation services and true IP based real-time multimedia. One of the key challenges in future network management is end-to-end optimization that takes into account variables such as throughput optimization, routing optimization, delay profiles for heterogeneous wireless environments and also economical profitability. The door for next generation networks and services beyond 3G is opening and is soon ready for entering. These systems are called next generation or 4G. They will make heavy use of heterogeneous networking technologies.

III. CLASSIFICATION OF VERTICAL HANDOVERS

The handovers can be classified in many different ways. However, for vertical handover (VHO), there are two additional and useful classifications to facilitate understanding as to why vertical handover mechanisms are different from traditional horizontal handover mechanisms.

The first classification is:

a) upward vertical handover and
b) downward vertical handover

An upward vertical handover occurs from a network with small coverage and high data rate to a network with wider coverage and lower date rate. On the other hand, a downward vertical handover occurs in the opposite direction. As an example for this classification let's consider the two of the most important current wireless technologies: 3G cellular networks and WLANs. The WLAN system can be considered as the small coverage network with high data rate while the 3G cellular system is the one with wider coverage and lower data rate. The trend in the literature has been to perform downward vertical handover whenever possible.

The second classification is:

a) imperative and
b) alternative

An imperative vertical handover occurs due to low signal from the base station or access point. The execution of an imperative vertical handover has to be fast in order to keep on-going connections. A vertical handover initiated to provide the user with better performance is considered to be an alternative vertical handover. This vertical handover can occur when a user connected to a 3G cellular network goes inside the coverage of a WLAN, even if the signal of the connection to the 3G cellular networks does not lose any signal strength, the user may consider the connection to the WLAN a better option.

In order to find the best network, the handover decision mechanism requires more information and parameters to decide which network to perform a handover to. These information and parameters are commonly referred to as handover metrics. They are qualities and quantities that are measured to give an indication of whether or not a handover is needed and they may also help to decide the target network. While the main metric in horizontal handover is the received signal strength from the BSs, in vertical handover there are more parameters that need to be considered. Examples include: the different data rates offered, coverage areas, access costs, security capabilities, and communication services.

As far as we are aware, the algorithms concerned with the vertical handoff recorded in literatures can be classified to four main directions. The first approach takes the received signal strength (RSS) and some other factors, such as bandwidth, delay and distance, into consideration to select the best network through a simple comparison. The second approach utilizes the artificial intelligence techniques, such as neural network, fuzzy control and machine learning, combining the factors considered in the first approach to select the best network. The third direction is based on cost/benefit value which is a function of several metrics, such as bandwidth, delay, access cost and power consumption, etc. Nodes select the network which corresponds to the minimum cost or maximum benefit by comparing the costs in different networks. The above three methods mainly consider the quality of service of nodes after handoff, but not consider the overall system performance, such as resource utilization affected by handoffs. The fourth approach resolves the above problem, which is based on the resource management, and the handoff execution of a node is used to make the resources optimally utilized. The fourth approach has become a new research direction in the vertical handoff algorithm in the heterogeneous networks. However, all the four approaches are not irrelevant and they could complement each other and form a new handoff decision algorithm.

IV. HANDOVER FROM WIRELESS LAN TO UMTS

In this section, we describe the handover protocol from Wireless LAN to UMTS only. The Wireless LAN Access Point is an integral part of the UMTS network. It is directly connected to the *Serving GPRS Support Node* (SGSN) and thus represents an alternative radio access network to the existing cellular one. The *Mobile Equipment* (ME) itself is equipped with two interfaces, a Wireless LAN interface and a UMTS interface, which are connected to each other and the network layer by a handover module. Whenever the ME moves out of the coverage area of a Wireless LAN cell, indicated by measurement reports to the SGSN, the vertical handover is initiated. The green arrows indicate transmissions using Wireless LAN and the blue ones are UMTS transmissions. The vertical handover process is split into three parts, the connection establishment, the handover procedure, and the connection release.

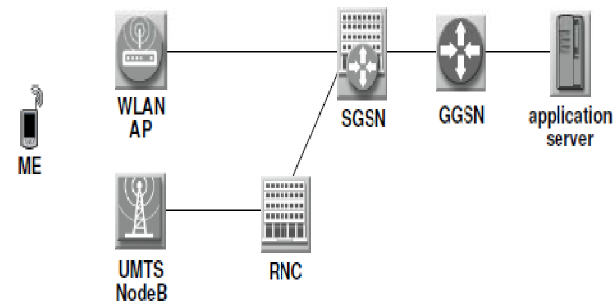

Figure 3. Network Architecture

The process is initiated by sending a UMTS device activation request from the SGSN to the mobile equipment using the existing Wireless LAN connection. In return, the ME sends a *Packet Data Protocol* (PDP) context request for every quality of service class used in Wireless LAN over the UMTS shared channel back to the SGSN. This is followed by the *Radio Access Bearer* (RAB) setup and the creation of a tunnel between the RNC and the SGSN.

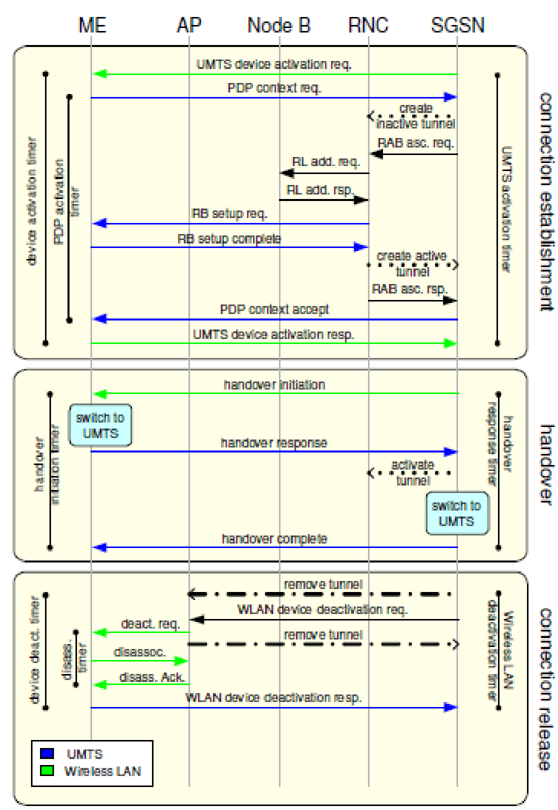

Figure 4. Vertical Handover Protocol for LAN to UMTS

When all quality of service classes is active, the mobile equipment is connected to both networks and transmits a positive UMTS device activation response to the SGSN. After the successful connection establishment, the SGSN initiates the vertical handover itself, the switching of the networks. First, the ME switches to UMTS and indicates the change of devices to the SGSN with a handover

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response message. Then, the SGSN activates the IP-over-IP tunnel to the RNC and updates its address of the ME so that all traffic is forwarded to RNC which is responsible for the ME. Finally, to complete the vertical handover process, the old connection to Wireless LAN is dislocated to save resources.

Therefore, the tunnel between the SGSN and the Access Point is released and the ME disassociates to the Access Point. The connection establishment takes most of the time, especially for the Wireless LAN to UMTS handover. This results from the complex radio access bearer and tunnel setup. Unfortunately, this delay cannot be reduced and will always be around half a second for the UMTS connection setup and 230 ms for the Wireless LAN connection establishment.

V. A LOAD BALANCING SCHEME IN VERTICAL HANDOVER BY FUSSY NEURAL NETWORK

The fuzzy logic has been used to solve several routing protocols and handover problems efficiently in wireless networks. It helps to solver user bandwidth problems by determining the block probability, the drop probability and the number of users, where the block probability and the drop probability affect the system cost, and the number of users affects the system revenue, and all of them are determined by the new call arrival rate and the handoff call arrival rate, so the system benefit is a function of the two arrival rates.

There are lots of solutions on VLSI chips that allow fuzzy inferences to be hardware-computed, and high speed low cost fuzzy chips have been introduced recently. In our scheme, we first try a fuzzy logic approach to offer the self-tuning capability in load balance estimation mechanism, and compare its performance with that of the balancing fuzzy neural network (BFNN). The basic functions of the components employed in the scheme are described as follows.

a. ***Fuzzifier**:* The fuzzifier performs the fuzzification function that converts three types of input data from the fuzzy load balance scheme into suitable linguistic values, which are needed in the inference engine. The input to the fuzzifier V represents node velocity, which is a measure of network reconfiguration rate. The input N denotes the node density.
b. ***Fuzzy Rule**:* The fuzzy rule is composed of a set of linguistic control rules and the attendant control goals.
c. ***Inference Engine**:* The inference engine simulates human decision-making based on the fuzzy control rules and the related input linguistic parameters. The max-min inference method is used to associate the outputs of the inferential rules. The output of the inference engine, Lb, is defined as the load balance control action of our scheme.
d. ***Defuzzifier**:* The defuzzifier acquires the aggregated linguistic values from the inferred fuzzy control action and generates a non-fuzzy control output, which represents the estimated load balance adapted to the new network and node conditions.

VI. LOAD BALANCING ESTIMATION USING EVOLVING FUZZY NEURAL NETWORKS

Although we generated an exhaustive fuzzy rule base for the derivation of load balance in proposed protocol. A feed forward neural network is used to process fuzzified data and defuzzifies the fuzzy data as the output. The BFNN model not only gives the analogous performance compared with other advanced and complex neuro-fuzzy systems, but also provides the feature of the expeditious one pass parameter training which makes it highly suitable for the low power requirement in the load balance computation for wireless network.

The BFNN is mainly composed of five layers of neurons as shown in Figure. The fuzzy input layer carries out fuzzy quantization of the input variables, which are fed from the input layer. The rule layer contains rule nodes that can evolve through learning. These rule nodes reveal the prototypes of input–output data mapping that can be graphically represented as associations of hyper-spheres between the fuzzy input and the fuzzy output spaces. Each node of the fuzzy output layer represents fuzzy quantization of the output variables, and then the defuzzification for the fuzzy output variables get done in the output layer.

Generally, a BFNN consists of five processing stages, which are network initiation, inputs feed forward, parameters tuning, node aggregation and pruning, and rule extraction, respectively. After each input vector is fed into the BFNN, the BFNN updates the parameters, evolves connections, aggregates and prunes nodes based on the output error during the last epoch if necessary. Then the BFNN propagates the signals forward, and computes the output error again.

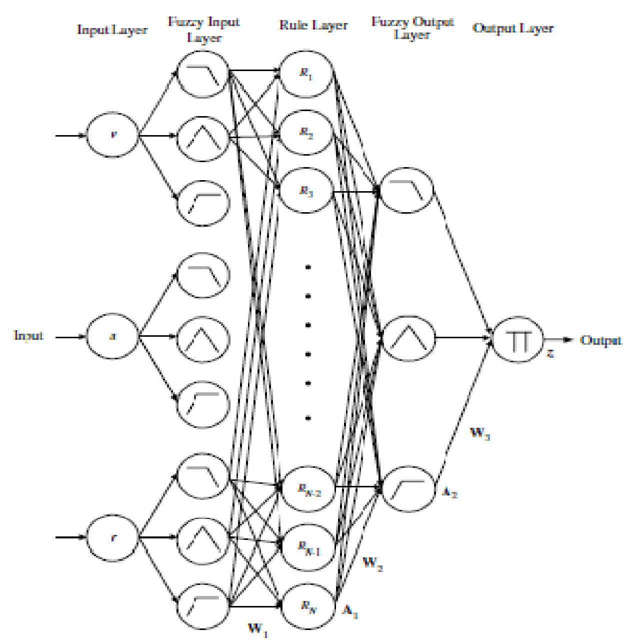

Figure 5. Architecture of evolving fuzzy neural network

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A. Network Initiation:

At the network initialization processing stage, the connection weights W1 and W2 as given in Figure are set to some predefined values based on the past experience of the network or the suggestions of the experts, which is similar to the way that the mean and variance of the membership functions is determined in the traditional fuzzy inference system. W1 represents the load balance in the fuzzy input space, and W2 the load balance in the fuzzy output space.

B. Inputs Feed Forward:

When a new sample is fed as input, it is first fuzzified at the fuzzy input layer, and then it is called fuzzy load between the output from the fuzzy input layer and the connections weights W1 are calculated to determine if the input falls into the input receptive field of some specific rule node. The fuzzy load between the two fuzzy membership vectors of input X_f and the connection weight of the j^{th} rule node W_1,j is defined as follows:

$$(\mathbf{x}_f, \mathbf{w}_{1,j}) = \frac{\|\mathbf{x}_f - \mathbf{w}_{1,j}\|}{\|\mathbf{x}_f + \mathbf{w}_{1,j}\|}$$

Where $\|\mathbf{x}_f - \mathbf{w}_{1,j}\|$ denotes the sum of all the absolute values of a vector that is obtained after vector subtraction of X_f and W_1,j, $\|\mathbf{x}_f + \mathbf{w}_{1,j}\|$ the sum obtained after vector summation of X_f and W_1,j, $W_1 = [w_{1,1}\ w_{1,2} \ldots w_{1,N}]^T$, and N is the number of the rule nodes.

C. Parameters Tuning:

The training process of the network involves the updating of the connection weights W_1 and W_2, the learning rate and the sensitivity threshold for each rule node. W_1 is adjusted via unsupervised learning based on the similarity between the fuzzy input vector X_f and the stored prototypes W_1,j for the jth rule node.

D. Node Aggregation and Pruning:

After certain number of training samples has been presented, some neurons and connections may be pruned or aggregated. If the fuzzy load for every two out of m nodes is less than some threshold for both connections W_1 and W_2, the m nodes can be aggregated into one single rule node with the connections and sensitivity threshold.

E. Rule Extraction:

Every rule node in the network can generate a fuzzy rule from W_1 and W_2 connections. Small threshold value such as 0.1 is used to disregard the rules with small and insignificant membership degrees to shorten the computation time.

VII. CONCULISION

This paper presents the vertical handover as an important element in the emerging next generation wireless networks. The vertical handover is classified, its difference with the traditional horizontal handover is explained and its steps are presented with focus on the vertical handover decision. The paper also introduced a vertical handover protocol using a tight-coupled network architecture, where the Wireless LAN Access Points are integrated into the UMTS network. The integration of diverse wireless technologies requires the design of intelligent vertical handoff decision algorithms to enable mobile users to be equipped with contemporary multi-interfaced mobile terminals to effortlessly switch network access and hence experience quality of services.

Fuzzy neural Networks which will use multi-criteria for vertical handover algorithm will effectively handle the handover metrics. This scheme has the potential to provide a better quality of service (QoS) to users' in future wireless communications.

A. Open issues:

There are several open issues that need to be further investigated in the integration of B3G wireless networks. Examples include the load balancing and traffic management among networks, Quality of Service (QoS) support during vertical handover, connection admission control, resource sharing and resource allocation, security and authentication, billing and operator agreements, and implementation details.

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