# An Intelligent Approach for Handover Decision in Heterogeneous Wireless Environment

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**Abstract**

Vertical handoff is the basic requirement of the convergence of different access technologies. It is also the key characteristic and technology of overlay wireless network with appropriate network interfaces. The integration of diverse but complementary cellular and wireless technologies in the next generation wireless networks requires the design of intelligent vertical handoff decision algorithms to enable mobile users equipped with contemporary multi-interfaced mobile terminals to seamlessly switch network access and experience uninterrupted service continuity anywhere and anytime. Most existing vertical handoff decision strategies are designed to meet individual needs that may not achieve a good system performance. In this paper an intelligent approach is used for vertical handover decision. The intelligence is based on the fuzzy logic approach. So here, fuzzy logic is used for network selection and decision making for vertical handover.

**Keywords:** Heterogeneous wireless network, Fuzzy logic, Fuzzification, Crisp value, Mobility Management.

## 1. INTRODUCTION

With the development of wireless communication technology, the service of wireless communication networks is upgrading extremely fast. Presently, there are many kinds of wireless networks available to fulfill different needs and requirements of mobile users. When users are roaming among various wireless networks, such as Wireless LANs and 3G, the interconnection of these different networks has become a problem. While a mobile terminal (MT) crosses the coverage boundary of two different systems, its ongoing connection must be seamlessly switched to a new network with a guaranteed QoS. Such a cross-system transfer of an ongoing connection is usually referred to as inter-system, or vertical handover.

Unlike a horizontal handoff that only occurs within the same network [1], a vertical handoff occurs in the heterogeneous wireless network when a mobile user changes its connection between different networks. The vertical handoff can happen in two ways. The first is Upward Vertical Handover. This occurs from a network with small coverage and high data rate to a network with wider coverage and lower date rate. The second one is Downward Vertical Handover. This occurs in the opposite direction. This occurs from a network with wide coverage and low data rate to a network with small coverage range and high data rate.

The traditional horizontal handoff research is emphasized on the received signal strength (RSS) evaluation of the mobile host (MH). However, in the case of vertical handoff, RSS evaluations and comparisons are insufficient for making an optimized vertical handoff decision. Many other metrics, such as service type, monetary cost, network conditions, system performance, mobile node conditions and user preferences, should be taken into consideration [2].

Now there is a need of vertical handover decision handover algorithm which will make the connection alive during the handoff session. In this paper we have proposed an handoff decision algorithm based on fuzzy logic.

## 2. SURVEY OF RELATED WORKS

Related work on vertical handoff has been presented in recent research literature. Several papers have addressed designing architecture for hybrid networks, such as the application-layer session initiation protocol (SIP) [3], the hierarchical mobility management architecture proposed in [4], and the *P*-handoff protocol [5]. However, these papers focused on architecture design and did not address the handoff decision point or the vertical handoff performance issues.

W. Zhang, in [6], proposes that the vertical handoff decision is formulated as a fuzzy multiple attribute decision-making (MADM) problem. Fuzzy logic is used to represent the imprecise information of some attributes of the networks and the preferences of the user. In [7], Pramod Goyal, and S. K. Saxena proposes the *Dynamic Decision Model,* for performing the vertical handoffs to the “Best” interface at the “best” time moment, successfully and efficiently. They proposed *Dynamic Decision Model* for VHO which adopts a three phase approach comprising Priority phase, Normal phase and Decision phase. Lorenza Giupponi and Jordi Pérez-Romero in [8] propose an innovative mechanism to perform joint radio resource management (JRRM) based on neuron-fuzzy in heterogeneous radio access networks. The proposed fuzzy neural JRRM algorithm is able to jointly manage the common available radio resources operating in two steps. The first step selects a suitable combination of cells built around the three available Radio Access Technology (RAT), while the second step chooses the most appropriate RAT to which a user should be attached. The proposed algorithm allows implementing different operator policies as well as technical and subjective criteria, such as the operator and user preferences when performing the RAT selection by means of appropriate inference rules and a multiple decision mechanism. In [9] Liu Xia, et. al proposes a novel vertical handoff decision algorithm for overlay wireless networks consisting of cellular and wireless local area networks (WLANs). The target network is selected using a fuzzy logic-based normalized quantitative decision algorithm. Rami Tawil, et. al in [10] proposes a Trusted Distributed Vertical Handover Decision (T-DVHD) scheme for the fourth generation wireless networks. The main goals of the T-DVHD are to decrease the processing delay and to make a trust handoff decision in a heterogeneous wireless environment. In [11] Imed Lassoued, et. al proposes a novel methodology to evaluate the performance of vertical handoff mechanisms. They proposed a framework that allows to simulate realistic scenarios and to evaluate the entire vertical handoff mechanisms in a coherent manner. The proposed methodology takes into account the users preferences, the applications requirements, the mobile terminal context and the operator constraints. In [12] Ben-Jye Chang and Jun-Fu Chen propose a cross-layer-based polynomial regression predictive RSS approach with the Markov decision process (MDP) based optimal network selection for handoff in heterogeneous wireless networks was proposed. The proposed approach consists of a two-phase procedure. In the first phase, a predictive RSS based on the polynomial regression with a hysteresis algorithm is proposed to predict whether a mobile node moves closer to or away from the monitored wireless network. In the second phase, the handoff cost is determined based on the MDP analysis. The candidate network with the lowest handoff cost is selected as the optimal handoff network.

## 3. TRIGGER MANAGEMENT SYSTEM

There are many events which affects the mobile device in heterogeneous wireless environment. After surveying the literature [13], [14]–[15], we identified more than one hundred different types of network events related to mobility management. These triggers and events can be cluster, regardless of the underlying communication technology, based on groups of events related to changes in network topology and routing, available access media, radio link conditions, user

actions and preferences, context information, operator policies, quality of service (QoS) parameters, network composition, and security alerts. In the mobility management, triggers can be classified and filtered based on five criteria: type, origin, occurrence/frequency, event persistence, and temporal constraints [16]. For example, we identified three trigger types based on whether an event may, will, or must force a HO. Origin corresponds to the entity that produces the trigger, for example, the radio access component. With respect to frequency of occurrence, an event may be either periodic (such as, network measurements) or asynchronous (such as, the availability of a new network access or a security alert). Finally, events can be either transient or persistent, and they may be associated with a real-time constraint. There are different types of events related to mobility management and vertical handover. The events that relate to application layer mobility management includes changes in QoS parameters, user preferences and security alerts. The events of network topology and routing information relates to transport and network layer. The events of radio link conditions, link parameters and available media bandwidth are some of the events that relate to the link and physical layers.
The figure 1 shows the events and triggers of different layers in mobility management [16]. Trigger management in mobility management gives a facility to improve delays and errors. Now consider the case where mobile has registered for a set of events, like available bandwidth, link status, network load etc. Now when the network load starts exceeding then after a certain threshold level, a trigger will be generated to describe the condition of the network load. This will make the mobile node to take a prior decision to switch to other available network.

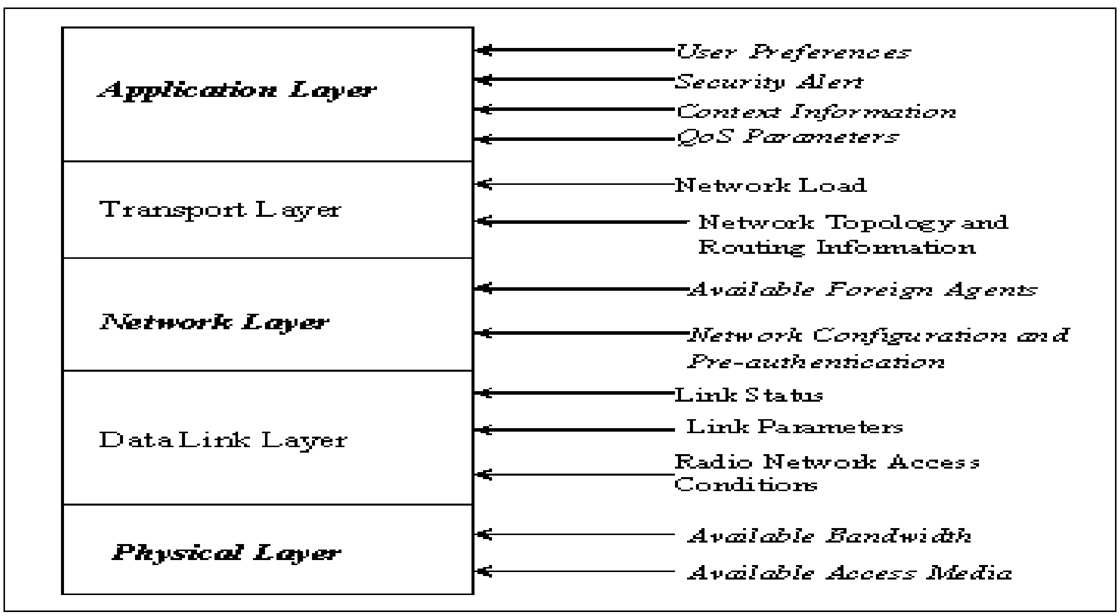


**FIGURE 1:** Event and Triggers of Different Layer in Mobility Management.

## 4. FUZZY INFERENCE SYSTEM

Fuzzy logic can be viewed as a theory for dealing with uncertainty about complex systems, and as an approximation theory. This perspective shows that fuzzy has two objectives (a) To develop computational methods that can perform reasoning and problem solving tasks that requires human intelligence and (b) To explore an effective trade-off between precision and the cost in developing an approximate model of a complex system.
Now in order to design a fuzzy logic system one has to be able to describe the operations linguistically. In other words one has to:

- Identify the inputs and outputs using linguistic variables. In this step we have to define the number of inputs and output terms linguistically.
- Assign membership functions to the variables. In this step we will assign membership functions to the input and output variables.

- Build a rule base. In this step we will build a rule base between input and output variables. The rule base in a fuzzy system takes the form of IF---AND---OR, THEN with the operations AND, OR, etc.

The fuzzy inference system is shown in Figure 2 which shows the input, output and fuzzy rules.

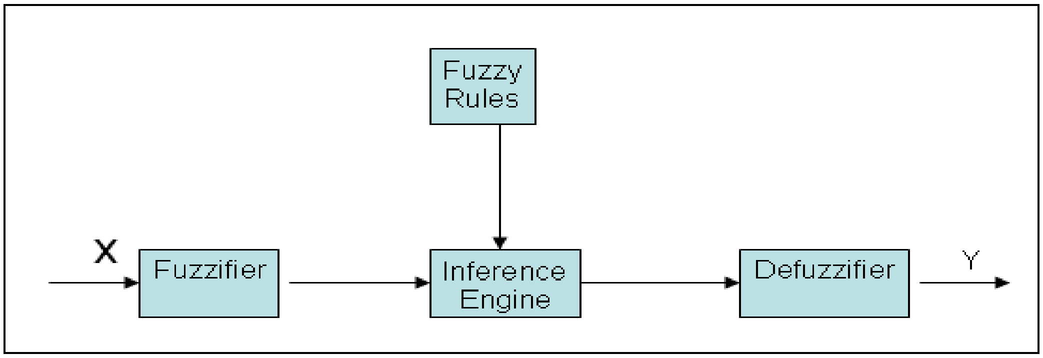


**FIGURE2:** The Fuzzy Inference System

## 5. ARCHITUCTURE OF PROPOSED INTELLIGENT HANDOVER DECISION MODEL

Heterogeneous access through multiple network interfaces is the current trend in the new generation of mobile devices. Managing the complexity of different access schemes, amount of bandwidth and cell coverage in multiple-interface devices is becoming a critical aspect to face. Namely, with multiple-mode mobile devices it is necessary to provide seamless mobility support not only during changes of cells of the same access network, but also during movement between access technologies. So we need vertical handover to use the best characteristic of any technology at one time and another at any other time. This handover decision should be intelligent enough to take the decision spontaneously. As for real time applications we need more bandwidth and connection must be alive all the time so decision should be intelligent which cater QoS requirement and witching among networks should be at right time.

Here we propose a model which gathers events from link layer, network layer and transport layer and takes decision based on fuzzy rules.

For our model we choose different variables, i.e.

- Signal Strength
- Network load
- Available Bandwidth

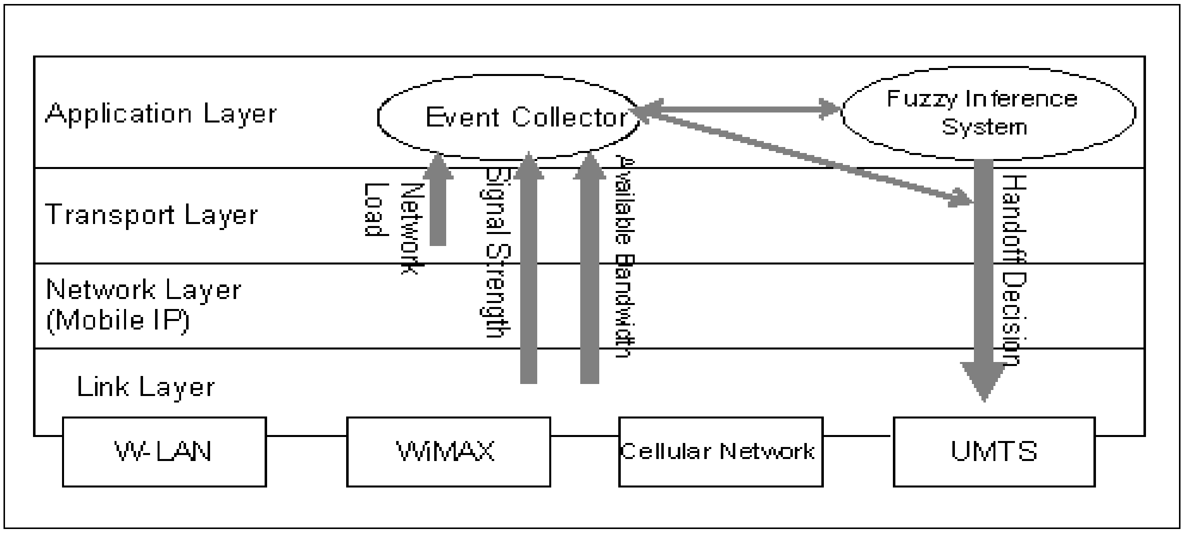


**FIGURE3:** Proposed Handover Decision System

Figure 3 shows the model for handover decision system. It represents 4 layers of the OSI model, which are in more focus in this model. Link layer triggers the changes in interface signal strength and the bandwidth provided by the operator company. Network layer supports mobility in heterogeneous environment and Transport layer represents network load. Network load can be observed by checking congestion or flow of packets at transport layer. The values of the events generated by event generator are feed to the fuzzy inference system. The output of the fuzzy system is the handover decision.

Event collector in application layer will collect events from different layers, i.e., if the available bandwidth is less than the required bandwidth then that interface will generate event that will be collected by Event collector. Then all these events and triggers are forwarded to fuzzy expert system as crisp input, then the information from the rule base is taken and inputs are evaluated. Event collector maintains states of every interface variable for further processing and also maintains final output selection that is returned from fuzzy expert system.

## 6. SYSTEM SIMULATION AND RESULTS

For system simulation Sugeno Fuzzy Inference system was used. Fuzzy inference collects input values of signal strength, network load and available bandwidth from event collector as crisp inputs and then evaluates them according to rules. The crisp input is then evaluated using rule base. The composed and aggregated output of rules evaluation is defuzzified and crisp output is obtained. Figure 4, 5, and 6 shows the fuzzy input variable for the available bandwidth, network load and Signal strength respectively. Each of the fuzzy variables has three subsets. These sets are mapped to the corresponding Gaussian membership functions. Since here we are using the fuzzy input variables and each of them has three subsets so there are $3^3$ =27 rules. These rules are given in the Appendix.

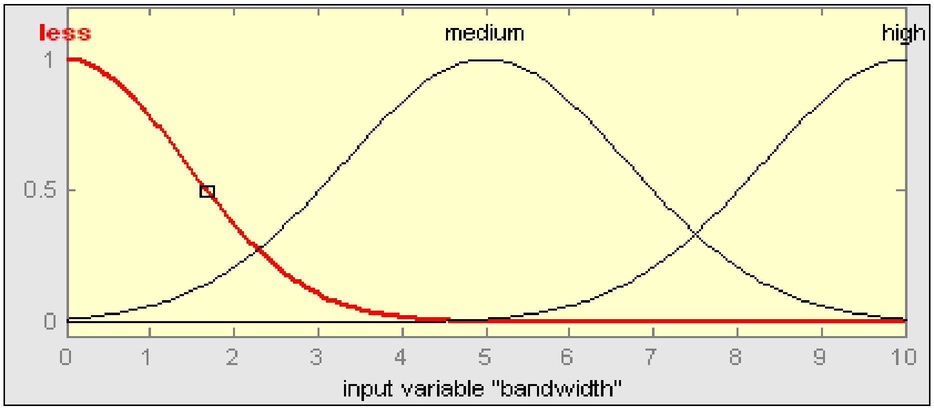


**FIGURE4:** Fuzzy Input Variable “Available Bandwidth”

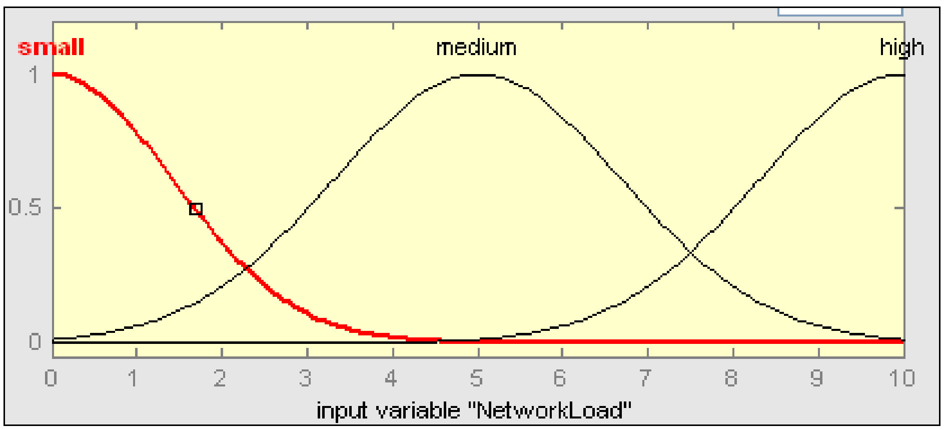


**FIGURE5:** Fuzzy Input Variable “Network Load”

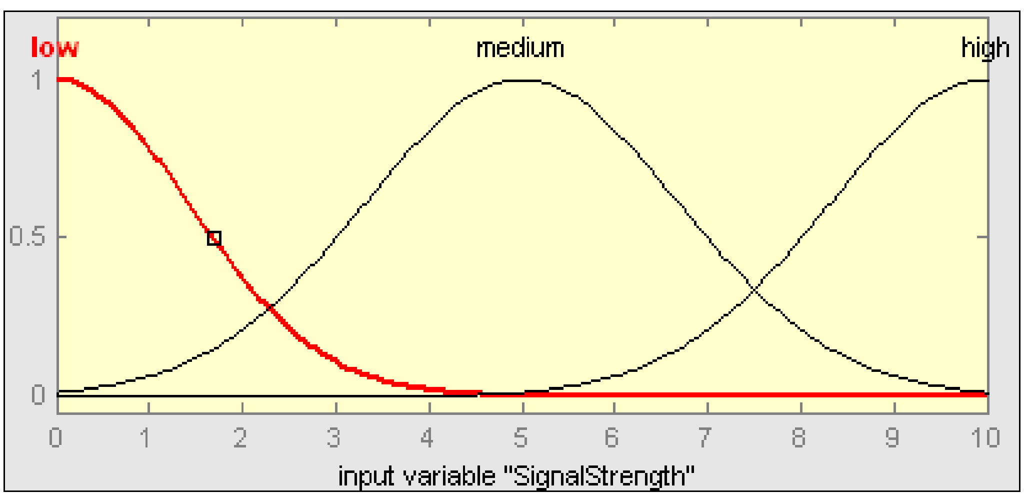


**FIGURE6:** Fuzzy Input Variable “Signal Strength”

The fuzzy set values for the output decision variable Handoff Decision are NO, Probably Yes (PY) and Yes (Y). The universes of discourse for the variable Handoff is defined from 0 to 1.

Now let us consider a mobile device currently in a W-LAN network. All the network interface variables, i.e. Network Load, Available bandwidth and Signal Strength of the current network are known. Now as the device moves from one place to another where cellular network and UMTS

networks are available, the device interface for cellular network and UMTS starts receiving signals. As the new signals are received, the triggers of its variable will be generated. The device will evaluate network variables of current network with the new one make a decision of vertical handover depending on current application requirement.
Now the crisp inputs of network variables are entered in the fuzzy inference system trough which they pass to the rule base to evaluate the output crisp value for network selection.

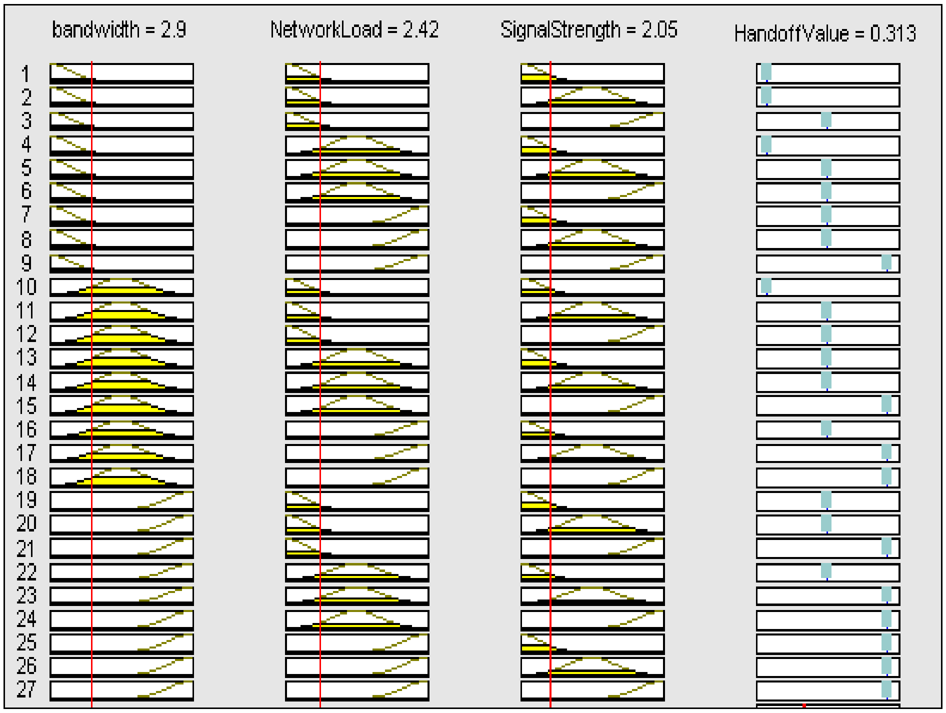


**FIGURE 7**: Rule Base for W-LAN Network

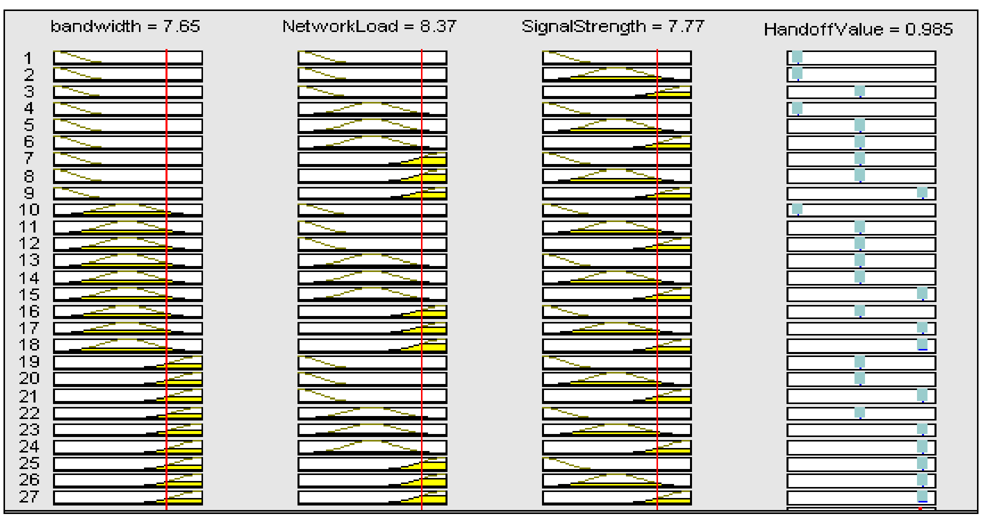


**FIGURE 8:** Rule Base for UMTS Network.

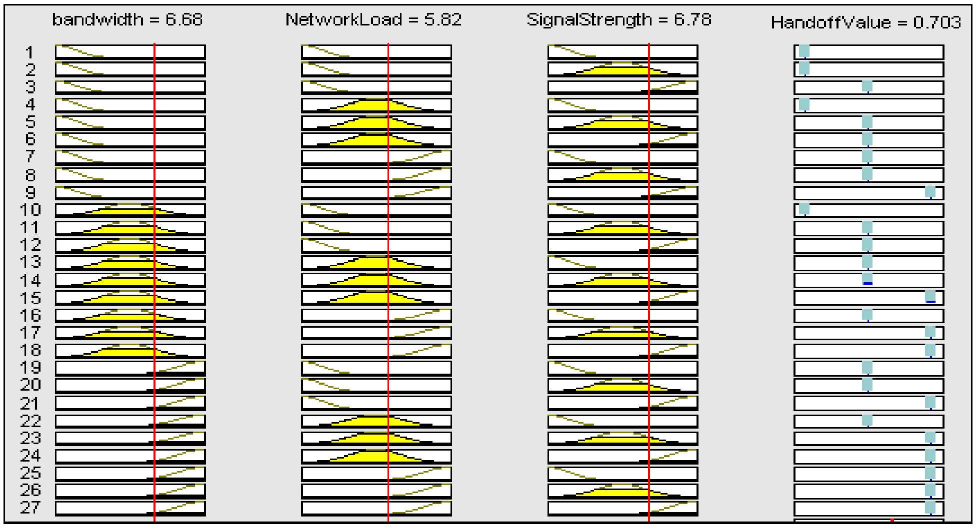


**FIGURE 9:** Rule Base for Cellular Network

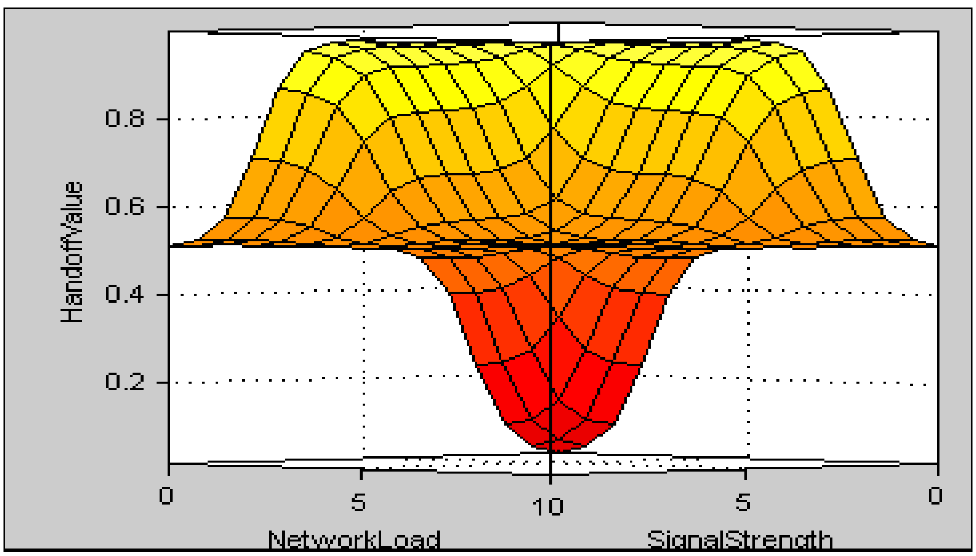


**FIGURE 10:** Surface Curve Between Network Load, Signal Strength and Handoff Value

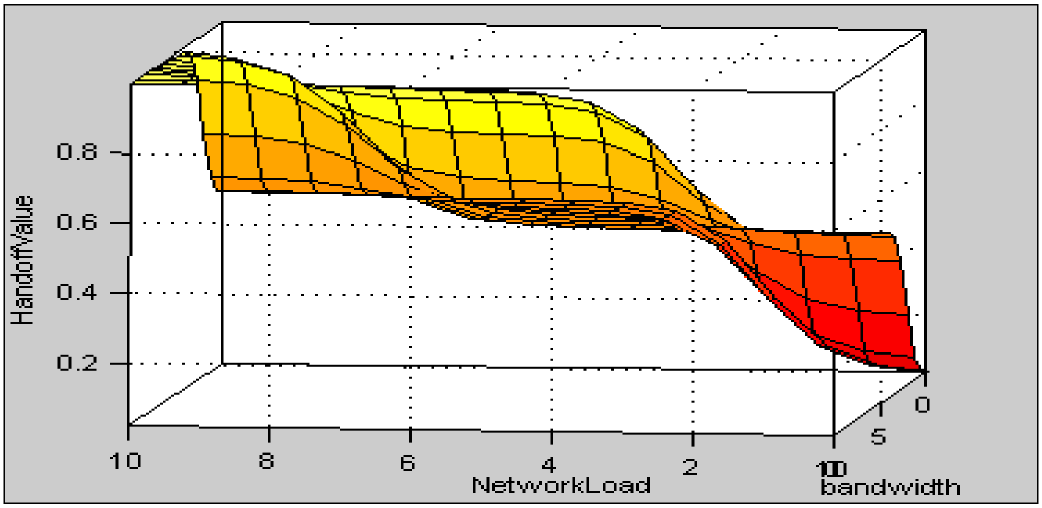


**FIGURE 11:** Surface Curve Between Network Load, Available Bandwidth and Handoff Value.

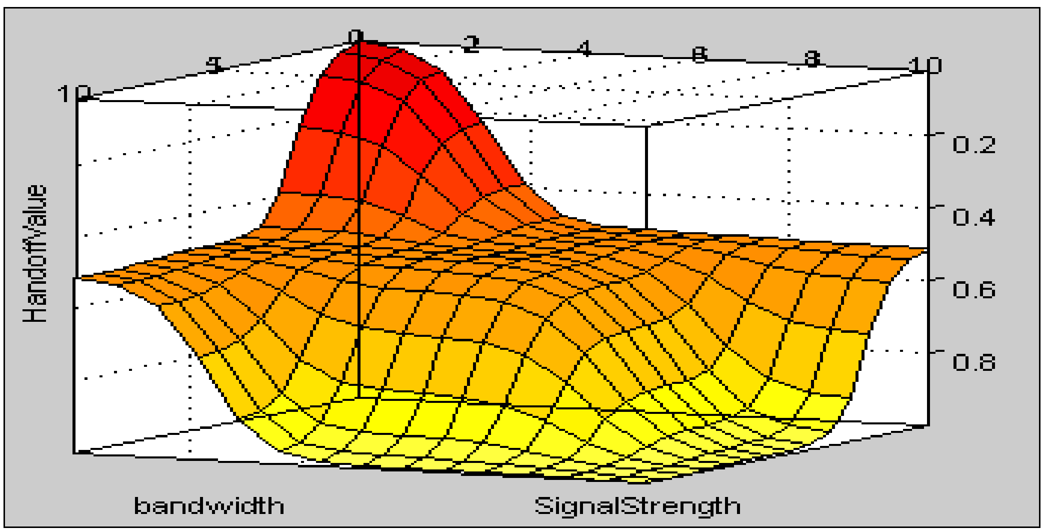


**FIGURE 12:** Surface Curve Between Signal Strength, Available Bandwidth and Handoff Value.

Now consider for example, that the crisp input value of current W-LAN network for network variable Bandwidth, Network Load and Signal Strength be 2.29, 2.42 and 2.05 respectively. As the device moves from one place to another where Cellular Network and UMTS are available. The input crisp value of new network i.e. for UMTS the value for network variables Bandwidth, Network Load and Signal Strength is 7.65, 8.37 and 7.77 and similarly for cellular network the input crisp value are 6.68, 5.82 and 6.78 respectively. Now putting these values to the Sugeno fuzzy expert system, the crisp output for network selection is obtained for W-LAN, UMTS and Cellular Network. Figure 7, 8 and 9 shows the rules evaluation phase of fuzzy expert system for W-LAN, UMTS and Cellular Networks respectively. Figure 10, 11 and 12 shows the surface curves between Network Load, Available Bandwidth, Signal Strength and Handoff Values.
Crisp output obtained from networks from fuzzifier is forwarded to the comparator to make final decision about the interface selection. From the above example, the crisp value of handoff output for W-LAN is .313 (No), for UMTS is .985 (Yes) and for Cellular Network is .703 (PY). So UMTS will be selected.

## 7. CONCLUSION

Here an intelligent approach is proposed to find out the vertical handover decision in multi network environment. The Sugeno Fuzzy Inference system is used to find the decision for vertical handover. The inference use the crisp input values for network parameters such as available bandwidth, network load and signal strength. The value of these network parameters are generated by event generator and are feed fuzzy inference system. The output of the fuzzy system is handover decision. In this way an intelligent decision will be taken based on output values.

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## APPENDIX

**RULES:** The rule blocks contain the control strategy of a fuzzy logic system. Each rule block confines all rules for the same context. A context is defined by the same input and output variables of the rules. The rules 'if' part describes the situation, for which the rules are designed. The 'then' part describes the response of the fuzzy system in this situation.

| **IF** | | | **THEN** |
|---|---|---|---|
| *AVAILABLE BANDWIDTH* | *NETWORK LOAD* | *SIGNAL STRENGTH* | *HANDOFF DECISION* |
| Less | Small | Low | NO |
| Less | Small | Medium | NO |
| Less | Small | High | PY |
| Less | Medium | Low | NO |
| Less | Medium | Medium | PY |
| Less | Medium | High | PY |
| Less | High | Low | PY |
| Less | High | Medium | PY |
| Less | High | High | YES |
| Medium | Small | Low | NO |
| Medium | Small | Medium | PY |
| Medium | Small | High | PY |
| Medium | Medium | Low | PY |
| Medium | Medium | Medium | PY |
| Medium | Medium | High | YES |
| Medium | High | Low | PY |
| Medium | High | Medium | YES |
| Medium | High | High | YES |
| High | Small | Low | PY |
| High | Small | Medium | PY |
| High | Small | High | YES |
| High | Medium | Low | PY |
| High | Medium | Medium | YES |
| High | Medium | High | YES |
| High | High | Low | YES |
| High | High | Medium | YES |
| High | High | High | YES |