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Mobility Management in 4G Networks

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Abstract - Over the past 25 years, the evolution of the internet and the advances of wireless technologies have made a tremendous impact on lifestyle of people around the world. Together, these two factors have changed the way people communicate, work, and get their entertainment. In order to be always best connected for various applications, the network selection procedure in heterogeneous multi-access environment during vertical handover decision is intended to choose the most suitable network for mobile user. In this paper, a performance study using the fuzzy logic concept is done and the integration of UMTS and WiMAX network is taken as an example to show that the proposed vertical handoff decision algorithm is able to determine when a hand off is required, and selects the best access network that is optimized to network conditions, quality of service requirements, received signal strength, bandwidth requirements and user preferences.

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Mobility Management in 4G Networks

Ruby Verma [α] & Pankaj Garg [σ]

Abstract - Over the past 25 years, the evolution of the internet and the advances of wireless technologies have made a tremendous impact on lifestyle of people around the world. Together, these two factors have changed the way people communicate, work, and get their entertainment. In order to be always best connected for various applications, the network selection procedure in heterogeneous multi-access environment during vertical handover decision is intended to choose the most suitable network for mobile user. In this paper, a performance study using the fuzzy logic concept is done and the integration of UMTS and WiMAX network is taken as an example to show that the proposed vertical handoff decision algorithm is able to determine when a hand off is required, and selects the best access network that is optimized to network conditions, quality of service requirements, received signal strength, bandwidth requirements and user preferences.

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I. Introduction

IP based mobile telecommunication networks are the next big jump in the mobile telecommunication industry. 4G networks will allow users to roam over a variety of radio access networks such as WLAN, W-CDMA and CDMA2000 by integrating mobility management mechanisms and vertical handoff schemes at the network layer. WiMAX technology brought revolution in both fixed and mobile wireless communication. In present communication world, wireless communication does not mean only data and voice transmission. It also supports high data rate transmission which supports various types of service like voice, data, and multimedia [1].WiMAX embedded devices support the Wi-Fi standards. So the people who are using Wi-Fi can easily switch to WiMAX technology. Moreover, in the developing countries the high data rate wireless communication infrastructure is not strong enough. WiMAX can be a good solution for these countries which is more secured, reliable and cheap. For these reasons the users of this technology are increasing day by day. As WiMAX is the latest technology and better solution in the wireless communication world, so this technology is used and work is done on the mobility management between UMTS and WiMAX networks by using fuzzy toolbox.

A handoff decision scheme using fuzzy logic is proposed in [10] that chooses the correct network with the imprecise information of some criteria and user preference. This algorithm will help to reduce the call Dropping probability in vertical handoff with the help of redetection of signal. In this vertical handoff algorithm, the Predictive Received Signal Strength (PRSS) is used to decide when to start a vertical handoff for WWAN to WLAN. Based upon input parameters like predicted RSS, bandwidth and users preference the value of handoff decision is calculated by the handoff decision algorithm. Taking idea from this algorithm, the proposed algorithm in this paper is more optimized as it also takes into account the network conditions and network coverage area and it is used to carry out handoff between 3G networks (UMTS) and 4G networks (WiMAX).

A handoff algorithm using fuzzy concepts must be capable of making a decision based on incomplete information and in a region of uncertainty. An adaptive multi-criteria handoff decision algorithm that incorporates fuzzy logic is used because of the inherent strength of fuzzy logic in solving problems exhibiting imprecision and the fact that many of the terms used for describing radio signals are fuzzy in nature. In conventional handoff decision only Received Signal strength (RSS) power level received from candidate base stations is compared. However, to optimize a handoff decision, other factors like bandwidth, network coverage and user preference should also be considered. Fuzzy logic can be exploited to develop approximate solutions that are both cost-effective and highly useful. In this paper, two handoff scenarios are considered, one is handoff from UMTS to WiMAX, and other is handoff from WiMAX to UMTS.

II. Proposed Handoff Algorithm

In this algorithm, if the mobile terminal is connected to the UMTS and the velocity of the mobile terminal (V) is higher than a velocity threshold (V_T) handover to the WiMAX is directly initiated to prevent a connection breakdown. Otherwise, the pre-decision unit checks whether the predicted RSS satisfies its requirements. If the predicted RSS from the UMTS (PR_w) is larger than its threshold (P_{rW}), or the predicted RSS from the WiMAX (PR_U) is smaller than its threshold (P_{rU}), no handover is triggered. After the pre-decision, the fuzzy logic based normalized quantitative decision (FNQD) is applied. The FNQD has three procedures: fuzzification, normalization and quantitative decision. The four inputs, received signal strength (RSSI), bandwidth/ data rate available, network coverage area and perceived Qos, are fuzzified and normalized to

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generate performance evaluation values (PEV), and the vertical handoff decision (VHD) is made by comparing PEVs of the network candidates. If the mobile terminal is connected to the WiMAX and the UMTS connectivity is available, the pre-decision unit is used to eliminate unnecessary handovers when the velocity of the mobile terminal is larger than the threshold (V_T). The process of this algorithmic illustrated in Figure 1.

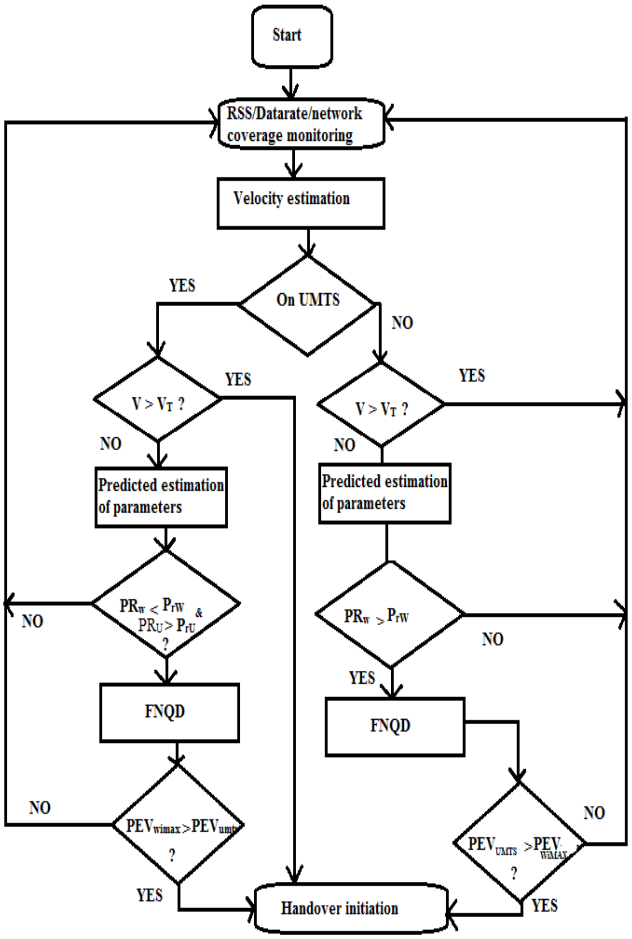

Figure 1 : Vertical handoff decision heuristic (VHD)

III. Fuzzy Inference System for Handoff

Inference is the process that draws conclusions from a set of facts using a collection of rules. The fuzzy inference system is a computing framework based on the concepts of fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning. Mamdani and the Sugeno are the two types of fuzzy inference systems that can be implemented. The differences between these fuzzy inference systems lie in the consequents of their fuzzy rules, and therefore their aggregation and defuzzification processes differ accordingly. The fuzzy inference engine is based on the Mamdani fuzzy inference system whose computational performance is more efficient than the Sugeno system and it consists of following functional blocks:

a) Fuzzifier which transforms the crisp inputs into degrees of match with linguistic values.
b) Fuzzy rule base which contains a number of fuzzy IF-THEN rules.
c) Database which defines the membership functions of the fuzzy sets used in the fuzzy rules.
d) Fuzzy inference engine which performs the inference operations on the fuzzy rule.
e) Defuzzifier which transforms the fuzzy results of the inference into a crisp output.

The handoff decision is shown in Figure 2. Vertical handoff decision in a heterogeneous wireless environment depends on several factors. A handoff decision in a next generation wireless network environment (including WWAN, WLAN, WiMAX and Digital Video Broadcasting) must solve the following problem: given a mobile device connected to an access network, determine whether a vertical handoff should be initiated and dynamically select the optimum network connection from the available access network technologies to continue with an existing service or begin another service.

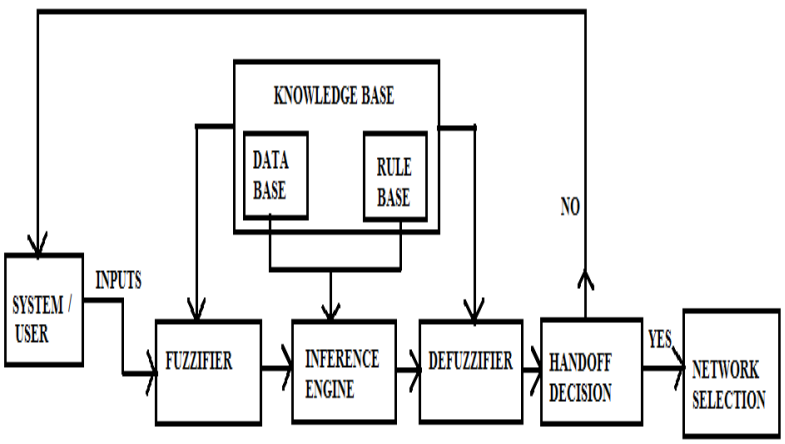

Figure 2 : Block Diagram for Vertical Handoff Decision

a) Handoff from UMTS to Wimax

Suppose that a mobile terminal (MT) is connected to a UMTS network and detects a new WiMAX network. Since the UMTS could be always on and the WiMAX is optional, the objective of the handoff from the UMTS to WiMAX is to improve the QoS. A user connected to a UMTS system would like to move into a WiMAX area and change the connection to WiMAX to obtain a higher bandwidth service at a lesser cost. The multimode mobile node associated with the UMTS monitors at repeated intervals and measures the RSSI of nearby WiMAX to see whether or not a better high data rate service is available. Input data from both the user and the system are required for the handoff decision algorithm, whose main purpose is to select an optimum wireless network for a particular service that can satisfy the following objectives: preferred user wireless network, good signal strength, good network coverage, optimum bandwidth, low cost, high reliability, and low network latency.

Input parameters like RSSI, data rate, network coverage area and perceived Qos of the target WiMAX network are fed into a fusilier in a Mamdani FIS, which transforms them into fuzzy sets by determining the degree to which they belong to each of the appropriate fuzzy sets via membership functions (MFs).

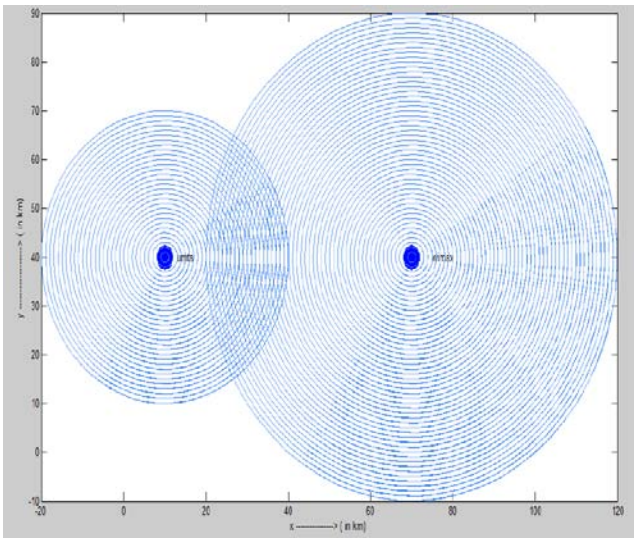

Figure 3 : Range of UMTS and WiMAX simulated in MATLAB

Next, the fuzzy sets are fed into a fuzzy inference engine where a set of fuzzy IF-THEN rules is applied to obtain fuzzy decision sets. The output fuzzy decision sets are aggregated into a single fuzzy set and passed to the defuzzifier to be converted into a precise quantity, the handoff factor, which determines whether a handoff is necessary. The range for WiMAX and UMTS is shown in Figure 3.

Each of the input parameters is assigned to one of three fuzzy sets; for example, the fuzzy set values for the RSSI consist of the linguistic terms: Strong, Medium, and Weak. These sets are mapped to corresponding Gaussian MFs. The universe of discourse for the fuzzy variable RSSI is defined from -78 dBm to -66 dBm. The universe of discourse for the variable Data Rate is defined from 0 Mbps to 60 Mbps, the universe of discourse for the variable Network Coverage is defined from 0 m to 50 Km [6], and the universe of discourse for the variable Perceived Quos is defined from 0 to 10. The fuzzy set values for the output decision variable Handoff are {Yes (Y), Probably Yes (PY), Uncertain (U), Probably No (PN), and No (N)}. The universe of discourse for the variable Handoff is defined from 0 to 4, with the maximum membership of the sets "No" and "Yes" at 0 and 4, respectively. Since there are four fuzzy input variables and three fuzzy sets for each fuzzy variable, the maximum possible number of rules in our rule base is $3^4 = 81$. The fuzzy rule base contains IF-THEN rules such as:

a) IF RSSI is weak, and available data rate is low and network coverage area is bad, and perceived Qos is undesirable, THEN handoff is N.
b) IF RSSI is weak, and available data rate is low, and network coverage area is medium and perceived Qos is acceptable, THEN handoff is PN.
c) IF RSSI is strong, and available data rate is high, and network coverage area is good and perceived Qos is desirable, THEN handoff is Y.
d) IF RSSI is strong and available data rate is medium and network coverage area is medium, perceived Qos is acceptable, AND THEN handoff is PY.
e) IF RSSI is medium and available data rate is high and network coverage area is good, and perceived Qos is desirable, THEN handoff is Y.
f) IF RSSI is medium and available data rate is low and network coverage area is medium and perceived Quos is undesirable, THEN handoff is U.

Figure 4 (a) shows a MATLAB-based Mamdani fuzzy logic inference display of the combined six IF-THEN rules indicated above and (b), (c), (d), (e) shows the Surface Viewer for the system composed of these six rules in three specific cases with other two parameters taken as constant.

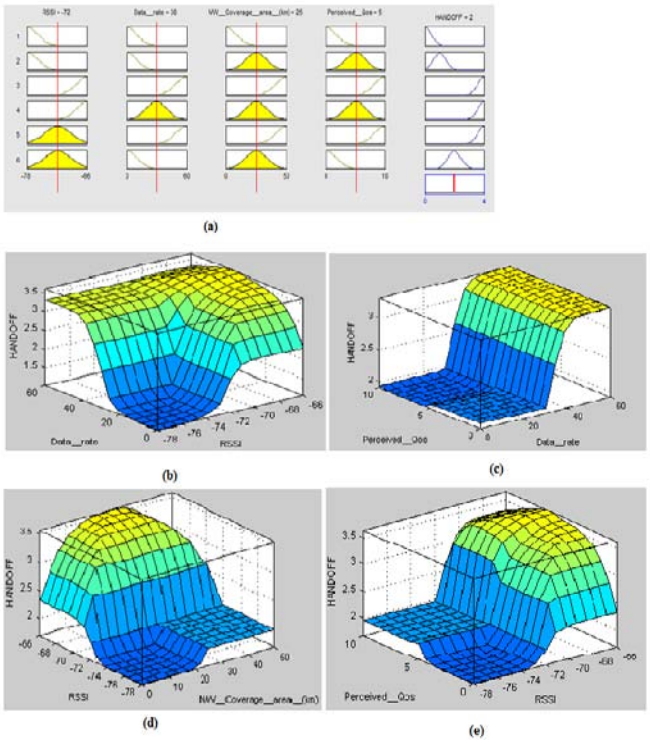

Figure 4 : (a) IF- THEN rules used in fuzzy block for UMTS to WiMAX; (b) Surface Viewer in case of constant network coverage and QoS; (c) Surface Viewer in the case of constant network coverage and RSSI; (d) Surface Viewer in the case of constant data rate and Qos; (e) Surface Viewer in the case of constant network coverage and data rate.

The crisp handoff factor computed after defuzzification is used to determine when a handoff is required. If handoff factor > 2, then initiate handoff, otherwise do nothing.

b) Handoff from WiMAX to UMTS

The parameters that are used in this directional handoff include the RSSI, data rate, network coverage area, and perceived Quos of the current WiMAX network. The design of the fuzzy inference system for this handoff scenario is similar to the design of the fuzzy inference system for the UMTS-to-WiMAX handoff. The fuzzy rule base contains IF-THEN rules such as:

a) IF RSSI is weak, and data rate is low, and network coverage area is bad, and perceived Quos is undesirable, THEN handoff factor is Y.
b) IF RSSI is weak, and data rate is low, and network coverage area is medium, and perceived QoS is undesirable, THEN handoff factor is PY.
c) IF RSSI is strong, and data rate is high, and network coverage area is good, and perceived QoS is desirable, THEN handoff is N.
d) IF RSSI is strong, and data rate is medium, and network coverage area is medium, and perceived QoS is undesirable, THEN handoff is PN.

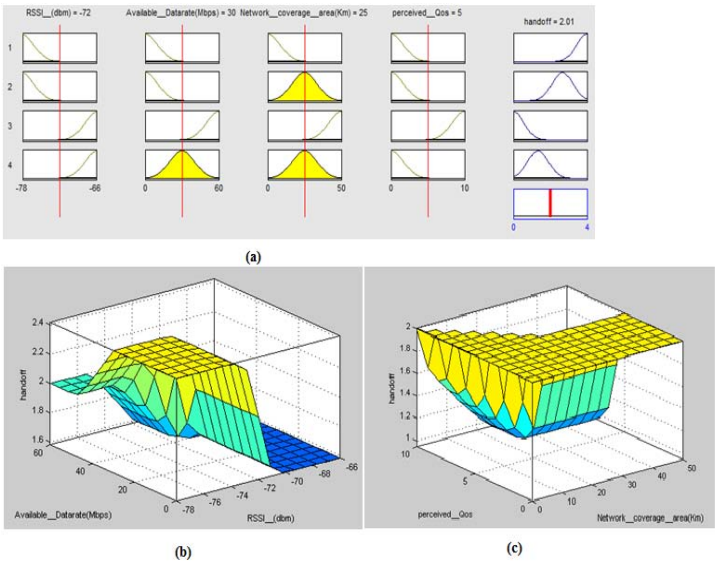

Figure 5 : (a) IF- THEN rules used in fuzzy block for WiMAX to UMTS; (b) Surface Viewer in the case of constant network coverage and Qos; (c) Surface Viewer for the fuzzy handoff in the case of constant RSSI and data rate

A MATLAB based fuzzy logic inference displays of the combined four IF-THEN rules indicated above are shown in Figure 5 (a) and (b), (c) shows the Surface Viewer for the system composed of these four rules in three specific cases where any two parameters are constant.

IV. Conclusion and Future Work

As foreseen by many researchers, the next generation wireless mobile communications (4G) will be based on the heterogeneous underlying infrastructure integrating different wireless access technologies in a complementary manner. This paper has presented the

use of fuzzy logic concepts to design an adaptive multi-criteria vertical handoff decision algorithm that is both cost-effective and highly useful. For the handoffs initiated by mobile nodes, fuzzy logic based vertical handoff decision algorithm (VHDA) is employed to select the most appropriate network for the mobile nodes. Afterward, the selected mobile nodes are handed over to other nearby base stations. The simulation results show that the VHDA can make accurate handoff decisions, help to balance the network resources and improve the performance of the networks. This research will facilitate the evolution of seamless mobility of the next generation networks.

Since the RSS was used in this algorithm, it is predicted that this algorithm decreases the probability of occurring handoff. However, the proof and the simulation of the algorithm for both application types (data and voice) and also the proof of the probability of handoff occurring formula for a different time are considered for future work. Comparison with other Cellular handoff mechanisms can also be considered for future work.

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