Rough Set Approximation Framework for Smarter Vertical Handovers
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Abstract
Future multi-network interfaced devices aim to provide coordinated services within a diverse and dense network environment. Such heterogeneous network environments therefore create a strong demand for smarter vertical handoff solution to support seamless mobility. In this paper, we propose rough set based decision framework for vertical handoff in heterogeneous networks. We apply fuzzy decision to fuzzy-rough set which gives us the advantage of the constrain relationship between constrain set and goal set. Our framework performs knowledge reduction and derives better dynamic decision rule. In addition, it has the advantage to deal with the imprecise information of some criteria and user preferences.

I. Introduction

The rapid proliferation of Wi-Fi, cellular networks is leading towards evolutionary paths to support high-rate packet data services including WiBro/WiMAX, long-term evolution (LTE) and ultra mobile broadband (UMB). Many mobile phones support both Wi-Fi and third generation (3G) wireless. In such heterogeneous networks, the Vertical Handoff (VHO) becomes a critical issue[1]. Unlike horizontal handoffs in homogeneous networks, vertical handoffs are not reversible i.e. the motive of handoff from network technology N[A] to N[B] differs from motive of handoff from N[B] to N[A]. VHO primarily follows three steps: Handoff Initiation, Handoff Decision and Handoff Execution [2]. Handoff Decision was traditionally based on an evaluation of the received signal strength (RSS) between the base station and mobile node. However, all RSS-based comparative methodologies were not satisfactory to make a critical vertical handoff decision, as these techniques do not take into account the other criteria. We can consider other metrics/factors such as bandwidth, type of network, signal to interference ratio (SIR), mobile station battery, distance between the mobile and BS, traffic load, and mobile velocity.

II. Related Work

In recent time, artificial intelligence based decision algorithms have been presented for adaptive decision [3-4]. Pahlavan et al [5] explores multi-network architectural issues and proposes an advanced neural-network based vertical handover algorithm to satisfy user’s bandwidth requirement. Wang et al [6] defines a two-dimensional cost function that considers several factors such as service type, monetary cost, network conditions, system performance, mobile node conditions and user preferences. Hou et al [7] suggests a pure fuzzy logic based decision making algorithm using dynamic programming. Qingyang et al [8] describes a network selection scheme for an integrated cellular/WLAN system. The common shortcomings in the mentioned handoff schemes [5-7] are that they all do not explain a vertical handover trigger points. Yan et al [9] suggests an adaptive multi-criteria vertical handoff decision scheme based on pure fuzzy set which is not effective for larger data sets. In this paper, we discuss our rough set based decision framework that enables MS to make intelligent handoff decision based on multi-criteria.

III. System Model

Unlike the traditional VHO algorithms [10] that act on the basis of RSS for decision strategy, we consider multi-criteria based handoff scenario to develop adaptive handover scheme to improve the decision accuracy. A typical heterogeneous wireless environment is as shown in Fig. 1, where WLANs are collocated inside the coverage of a wireless cellular system.

3.1 Rough Sets and Handoff Decision Problem

The rough sets theory [11] is based on the assumption that every object in the universe is associated with a certain amount of information (i.e. data or knowledge). Further, the objects can be expressed by means of some attributes used for their description. Objects having the same description are indiscernible (similar) with respect to the available information. A rough set is defined by means of these two approximations. In case of an ordinary set (generally known as crisp), these two approximations coincide.

3.2 Rough Sets-Formal Definition

More formally, let us consider a set of n network profiles $\Pi = \{N_1, N_2, \ldots, N_n\}$ where each profile is described by a set of m attributes such as network service type, monetary cost(time based and volume based fee), network condition, coverage area interference, system performance, link capacity, losses, RTT mobile node conditions and user preferences, RSSI etc then; $Q = \{q_1, q_2, \ldots, q_n\}$ and $V_q$ is the
domain of the attribute q: $V = \bigcup_{q \in Q} V_q$. Equivalence relation upon $U$ be represented as $R$, then for every (non-empty) subset of attributes $P$ we have:

$$R = \{(x, y) \in U \times U : f(x, y)\}$$

where $f : U \times Q \rightarrow V$ is a total function such that for each, called information function. Lower approximation for $X$ can be denoted as following:

$$\tilde{R}(X) = \{x \in U : \exists y \in X \mid (x, y) \in R\}$$

Upper approximation for $X$ can be represented as:

$$\tilde{R}(X) = \{x \in U : \exists y \in X \mid (x, y) \notin R\}$$

if Upper and Lower approximation are equal then set $X$ is crisp or definable set; else set $X$ is Rough set; A rough set based analysis helps in the extraction of classificatory knowledge, particularly in a domain that exhibits non-unique classification. Fuzzy rough set is based on rough set and fuzzy set theories. To apply fuzzy decision into rough set, we transform the rough set into fuzzy-rough set by means of membership function.

IV. VHO Decision-making Algorithm Using FD

4.1 Fuzzy Decision

Fuzzy decision has an inherent ability to solve uncertainty and contradiction embedded within a problem, and is widely used in control-engineering and decision-making systems. This section proposes a novel algorithm that employs FL to fuzzy-rough set to make the VHO decision. Let us consider the following: $D$: a set of fuzzy decision with membership function as $\mu_d(x)$; $G$: a set of fuzzy goals with its membership function as $\mu_g(x)$; $C$: a set of conditions with its membership function as $\mu_c(x)$; Now in the process of decision, $D$ can be considered as the intersection operation of $G$ and $C$ i.e. $D = G \cap C$. If adopting membership function, the formula is $\mu_d(x) = \min(\mu_g(x), \mu_c(x))$, $x \in U$ (Fig. 2)

![Fig. 2. Fuzzy Goal, Fuzzy Decision and Fuzzy Constraints](image)

To achieve a definite result or conclusion instead of a fuzzy one requires realizing de-fuzzification of $D$ i.e. to find $X_{\text{optimal}}$ with largest membership. Thereby, we call $X_{\text{optimal}}$ as following: $X_{\text{optimal}} = \{x \mid \max \mu_d(x) = \max \min(\mu_g(x), \mu_c(x))\}$

4.2 Algorithm Steps

Any subset $S$ of the universe may be expressed with approximation or precision (union of elementary sets) using these blocks. The handover algorithm reacts upon the reception of multi-criteria forming subsets. Each subset $S$ may be characterized by two sets, called lower approximations and upper approximations as shown in Fig. 3.

1. Formulate the n-criteria data set
2. Use rough reasoning to set up a fuzzy rough set on the basis of Section 3.2 and section 4.1.
3. Adopt a membership functions for the algorithm to make the necessary transformation.
4. Apply fuzzy decision as explained in Section 4.1 to find optimal decision.

V. Conclusion

This paper proposes an intelligent vertical handoff algorithm across heterogeneous wireless networks based on rough set theory. We use rough set to perform knowledge reduction, taking advantage of the equivalence relation and partitions defined in data sets. Later, we convert the rough set to fuzzy-rough set to apply fuzzy decision. We do this transformation through the membership function. Our proposed decision making algorithm incorporates uncertain and contradictory metrics to make a comprehensive decision with little execution costs. Our proposed framework helps to perform knowledge reduction and derive dynamic decision rule that help mobile nodes to decide faster. This can also effectively reduce ping-pong effect. Knowledge reduction in RSHA saves the memory to store the rule bases, saves the time to search within the rule bases.

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VII. Reference