Autonomic Management for Personalized Handover Decisions in Heterogeneous Wireless Networks

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Abstract. The computation of good and optimal handover decisions is a significant problem in a heterogeneous network environment. This is exacerbated when the goal is to provide personalized services for mobile users as opposed to generic device metrics such as received signal strength. Personalized handover decisions should not only consider received signal strength, but also context information, user preferences, and other non-functional requirements. In this paper, we propose a novel autonomic management method for personalized handover decisions to satisfy end users' demands in heterogeneous wireless networks. We define two objective metrics for evaluating specific access points: access point acceptance value and access point satisfaction value.

Keywords: Personalized Handover Decision, Autonomic Management.

1 Introduction

Growth in ubiquitous and mobile computing systems has led to the early introduction of a wide variety of new access networks and Internet-capable devices [1]. As a result, multiple heterogeneous wireless access networks can be used at the same place and a mobile device can access them simultaneously [2]. A foreseen feature of these networks and mobile devices is the support of flexible and personalized handover decisions by dedicated devices to satisfy the demands of the end user using context information [3,4].

The current handover decision methods based on *Received Signal Strength (RSS)* or pre-defined simple policies do not provide good solutions because they do not take into account services that satisfy the preferences of a user at a given time, location, and/or application context. Therefore, handover decisions should

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be based on additional considerations, such as the capacity of each network link, usage charge of each network connection, power consumption of each network interface, battery status of the mobile device, and user preferences. We call these and similar data *context* information.

In this paper, we propose an autonomic handover decision method for satisfying the end user's demand for different types of services in heterogeneous wireless networks by using fuzzy logic and utility functions as part of the decision-making process. We call this method *AUHO*, which is an abbreviation for ***AU****tonomic* ***H****and****O****ver*. We define two objective metrics for evaluating the performance of *Access Points (APs)*: a) *Access Point Acceptance Value (APAV)* and b) *Access Point Satisfaction Value (APSV)*. Our algorithm supports the selection of the best AP (horizontal handover) as well as the best access network (vertical handover) using current user preferences and profile data, application requirements, and context information. The novelty of our approach is in using a combination of functional and non-functional requirements, filtered by the particular context.

2 Related Work

We present previous approaches for handover decision strategies proposed in the literature. We divide these studies into six categories based on the metrics or techniques used for handover decisions [5]: 1) RSS-based, 2) cost function-based, 3) user-centric, 4) Artificial Intelligence (AI)-based, 5) Multiple-Criteria Decision Making (MCDM), and 6) context-aware approaches. In summary, compared to our AUHO approach, none of these approaches provide sufficient flexibility in satisfying user needs, and most cannot adapt to a changing context. Additional details on each algorithm are provided in the following sub-sections.

RSS-based approaches cannot be applied to vertical handover decisions because of different characteristics of the heterogeneous wireless networks. Cost function-based approaches use a pre-defined cost function which is a measurement of the benefit obtained by handing over to a particular network [6]. Among the different criteria that a vertical handover decision takes into account, user preferences such as cost and QoS, are the most interesting policy parameter for a user-centric strategy [7]. The handover decision problem selects among a limited number of candidate networks from various service providers and technologies with respect to different criteria. This is a typical MCDM problem, which deals with choosing from a set of alternatives which are characterized by their attributes [8]. The concepts of *Fuzzy Logic (FL)*, *Neural Networks (NN)*, Expert Systems, and *Genetic Algorithms (GA)* from AI can be used to decide when handover should occur and which network to should be chosen among different available access networks [9]. The context-aware handover concept is based on knowledge of the context information of the mobile terminal and networks in order to make intelligent and better decisions [10]. Our comparative study shows different issues related to the handover decision problem: network performance, user satisfaction, flexibility, efficiency, and multi-criteria solution [5].

3 Proposed Approach

Our research hypothesis is that our AUHO algorithm always *maximizes end user satisfaction* by computing the optimal handover decision for different types of mobile services in heterogeneous wireless networks based on user preferences. Our approach is as follows. First, we define and categorize context information for handover decisions by surveying available information from mobile devices, networks, applications, and users. Second, we construct an information model to represent different data models of mobile devices, access networks, applications, policies, users, and contexts, because data from each of these entities come from different sources and are defined using different languages. Third, we develop a decision making algorithm by evaluating each access network using a *weighted* combination of context information, user preferences, and service requirements. Note that the weighting enables the decision method to be adjusted to better suit the needs of the end user. We define how to measure and evaluate the quality of each AP and then calculate the end user satisfaction for achieving our hypothesis. We define the concept of an "*acceptance value*" using a fuzzy logic-based classifier to process all relevant context information, regardless of whether different languages and formats are used. We then define the concept of a "*satisfaction value*" using a utility function based on user preferences. We then select the "*best satisfying*" AP for supporting *Context-aware Always-Best-Satisfying (CABS)* mobility based on a utility function that maximizes user preferences. Fourth, we evaluate the performance of the proposed method using a network simulator that we developed for testing handover decisions in heterogeneous wireless networks. Finally, we compare our method with other decision making algorithms, and show that our algorithm supports a CABS service, which other methods do not support.

We defined two objective metrics for handover decisions: an APAV and an APSV. The former represents the suitability of a particular AP for an end user based on a given set of user preferences. The latter represents how well a particular AP satisfies the needs of the end user based on his or her user profile, as used in this context. We calculate the APAVs and APSVs for all candidate APs, and determine the AP that best satisfies the current application and context requirements. If the new candidate AP is the same as the old AP, no handover is performed. In addition, if the APSV of the new AP is higher than that of the current AP, we must consider handover overheads such as latency. Otherwise, handover to the new AP is performed. This process is continuously repeated within a pre-defined timeout that is defined by profiling. This is a our algorithm's feedback control loop to achieve autonomic management. After connecting the best satisfying AP, we repeat a maintenance loop by evaluating the current connected AP. If a connected AP exists, the network selection task is stopped. We then calculate the APAVs of the current AP and calculate the APSV based on them. If the APSV of the current AP is lower than the pre-defined threshold, the handover decision task is started again and all candidate APs are evaluated to select the best satisfying AP.

Currently, we have evaluated our AUHO with two case studies: a) the same application using different user profiles, and b) different applications using the same user profile. The former tests different weighting factors for each user preference, while the latter tests different application requirements for the same user profile. We showed that our AUHO provides the best satisfying AP compared to other handover decision making algorithms [5].

4 Conclusions

Seamless mobility and roaming in next-generation networks is an important issue. In particular, a handover should support not only *Always-Best-Connect* mobility, but also *Always-Best-Satisfying (ABS)* mobility for providing personalized mobile services. In this paper, we have proposed a novel handover decision method for supporting ABS mobility based on the end user's preferences and context information. Our method determines the access network and the AP that can best satisfy the requirements of the end user for a particular context. We showed how autonomic management can be used for handover decisions.

For future work, we will optimize our algorithm to calculate APAVs and APSVs. We will find the optimized timeout value for periodic decisions. Finally, we will perform more tests and optimize by considering handover overhead and network performance.

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