Intelligent Network Access and Inter-System Handover Control in Heterogeneous Wireless Networks for Smart Space Environments

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Abstract

The next generation of mobile networks will support not just simple mobile connectivity but access to evolving smart space environments. It is expected that these systems utilise multiple radio access technologies, seamlessly integrated to form a heterogeneous wireless access network, thus enabling total ubitiqous computing. On the arrival of a service request from a smart space user or device, the network operator must assign one of the available access networks. Selecting the network that has the highest probability of providing the best Quality of Service (QoS) for a particular service type is an important consideration for overall network stability and QoS provisioning. In this paper we present aspects of intelligent radio resource management based on policy based call admission control to select the best available network and fuzzy logic based inter-system handover control. The admission controller admits a new user based on the current load and service mix in each available network.

Inter-system handover involves users changing connectivity from one access technology to another. Inter-system handover initiation can be due to reduced QoS, cost of connection, network availability or user context such as characteristics of user mobility. This paper presents a fuzzy logic based time decision algorithm for inter-system handover initiation. The algorithm selects the time at which to initiate an inter-system handover request and in doing so reduces the number of excessive inter-system handovers.

Introduction

Seamless intersystem roaming across heterogeneous wireless access networks will be one of the main features in the mobility management architecture of future generation mobile networks such as those envisaged in an integrated smart space environment [1]. A smart space is an environment in which users have total ubiquitous connectivity to a multitude of services and applications using a diverse range of wireless devices such a mobile terminals, PDAs, laptops etc [2,3]. The motivation for heterogeneous wireless networks arises from the fact that no one technology can provide the ubiquitous coverage and continuous high quality of service (QoS) levels across multiple smart space environments. It will therefore be necessary for a mobile terminal to employ various points of attachment to maintain network connectivity to a corresponding node at all times. 3G and 4G mobile networks will consist of multiple wireless access technologies such as WCDMA, EDGE and IEEE 802.11a/b WLAN coexisting in a heterogeneous access network environment. Each network access technology provides different levels of coverage and QoS as well as cost to the end user. Multi-modal terminals in a smart space environment will seamlessly roam between these access networks so as to maintain minimum QoS contracts and service level agreements for different applications and for the support of user preferences. The seamless mobility of users between different access technologies is seen as one of the key issues in resource and mobility management for future generation heterogeneous wireless networks [4]. With intersystem mobility, users will benefit from the different coverage and capacity characteristics of each network throughout the interconnected smart spaces. The range of anticipated services in a wireless smart space environment will introduce high variability in the required QoS and therefore, the most optimal access network can dynamically change. This paper addresses two important issues concerning radio resource management in future generation heterogeneous wireless access networks namely, call admission control and inter-system handover.

Policy based Call Admission Control

The proposed policy system architecture for network access management is shown in Figure 1. Policy system architectures tend to focus on the relationship between the points where the outcome of a policy is enforced, i.e. the Policy Enforcement Point (PEP) and the point where the decision on whether a policy decision is satisfied is taken, i.e. the Policy Decision Point (PDP) [5]. The PDP for network access control is implemented on a server within the network, where information such as network coverage, mobility support and current load are available, e.g. a base station controller in EDGE, radio network controller in UMTS or gateway router in WLAN. The data required by the access management policy engine is maintained in a policy repository. The policy repository makes available these policy parameters to the PDP in the decision making process. The network policy engine is responsible for selecting an access network on the arrival of a service request. These access control decisions are made in the PDP, which contains the network selector. The network selectors function is to assign an access network for the requested connection. The policy in the network selector is to choose the access network that is currently least loaded for the particular type of service request, i.e. voice, www, video streaming. Using this policy, the load is balanced between the available access networks and avoids one network becoming excessively loaded. The network selector determines the residual capacity for each service type via network capacity surfaces stored in the policy repository. The capacity surfaces for each network were obtained via simulations in which the service mix was gradually increased to the point where the QoS offered to the end user degraded below acceptable levels. The surfaces show the trade off between the different service types. The access decision from the PDP is sent to the PEP, which informs the requested mobile whether its connection request is granted and to which network it should connect. Due to knowledge of network capacity, this network selection policy provides a greater level of QoS to all users than simply allocating any network to a requesting user.

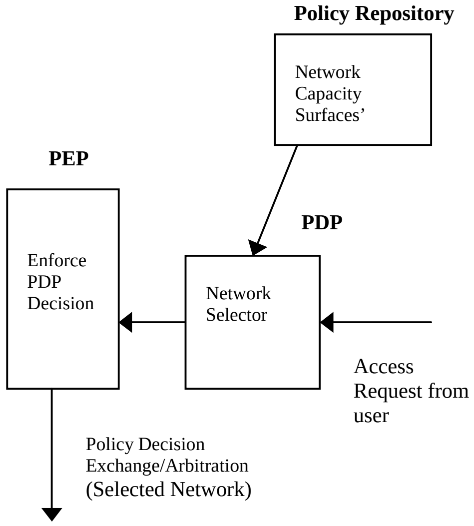

Figure 1. Policy Based Access Management

Inter-System Handover Initiation using Fuzzy Logic

Several proposals exist for intra-system handover in homogeneous wireless networks [6,7]. Such algorithms employ thresholds to compare values of metrics from candidate points of attachment. These metrics include, received signal strength (RSS), carrier to interference ratio (CIR), bit error rate (BER), block error rate (BLER), power budgets, mobile speed, and distance from the serving base station. In order to avoid continuous handover between two points of attachment, known as the ping-pong effect, hysteresis margins, dwell timers, and averaging windows are also used [6]. In contrast to intra-system handover, inter-system handover, which occurs between different overlaying access networks in a heterogeneous network, has a higher layer of complexity. The time in which an inter-system handover can occur is inherently much longer as the mobile terminal can maintain connectivity to many overlaying networks, each offering varying QoS to the end user. The optimal time to initiate the inter-system handover involves the processing of many parameters. Choosing the correct time to handover reduces subsequent handovers, improves QoS, and limits the signalling and rerouting of data inherent in the handover process.

The parameters we propose to use in the inter-system handover decision-making process include BLER, FDR, number of handovers executed for this session, time QoS has been below the predefine threshold, data held in user profile such as cost user is willing to pay for a service, preferred network, required QoS etc. In this work we are investigating the use of fuzzy logic to process these parameters and arrive at a decision whether to handover to another available network or to remain with the current access network expecting the current QoS level to improve and thus avoid unnecessary handovers. The architecture of the fuzzy logic controller is shown in Figure 2.

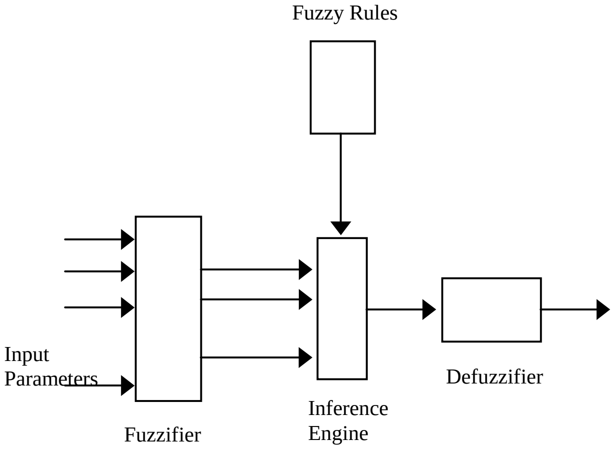

Figure 2. Fuzzy Logic Controller

The handover parameters are applied to the fuzzifier, where they are mapped into fuzzy sets. The fuzzy sets categorise each parameter as being Low, Medium or High, each with a value between 0-1. These are passed to the fuzzy inference engine where a set of fuzzy rules is applied to determine if an inter-system handover should occur at this time. There are two possible outcomes – handover or no handover. Example fuzzy rules for both handover and no handover conclusions are given below.

IF (FDR = Medium) AND (NHO = Low) AND (TAT = Medium) AND (COST = Low) THEN HO

IF (FDR = Medium) AND (NHO = High) AND (TAT = Low) AND (COST = High) THEN NOHO

where,
FDR = Frame Drop Rate
NHO = Number of Handovers already executed for this session
TAT = Time QoS has been above threshold
COST = Call tariff at an alternative network
HO = Handover
NOHO = No Handover

Each fuzzy rule is evaluated by taken the minimum condition value as the rule output. The maximum value for both the handover and no handover rules are then taken as the conclusions for both possible outcomes, this is known as the min-max rule, details of which can be found in [8]. The fuzzy rule base has been initially designed so that a handover will be trigged under the following situations depending on the strength of the output conclusions:

- The QoS falls well below the predefined threshold for a particular service type and the number of handovers executed for this session is low.
- The QoS falls just under the predefined threshold and remains in that state for duration considered to be long.
- An alternative network exists that offers the same QoS, but at a cheaper call tariff.

In all cases, the cost of implementing an inter-system handover must be within the range the user is currently willing to pay for a particular service. The cost membership function is updated to reflect changes made to a pricing variable stored in the user profile. The values associated with ‘well below’, ‘low’ and ‘long’ are design parameters of the fuzzy logic control system and are controlled by the network operator via membership functions [8]. The values assigned to both the handover and no handover outcomes are compared. A handover is triggered if the handover factor exceeds that of the no handover factor.

Simulation Model

The proposed policy based admission controller and fuzzy logic inter-system handover schemes are evaluated via a computer simulation model of a heterogeneous wireless access network. We consider three access technologies that provide connectivity to smart space users/devices, namely, EGPRS, UMTS and IEEE 802.11b. Users are positioned non-uniformly throughout the network. Three classes of service are considered, voice, web and video streaming, as these are expected to be among the most commonly used service types in future mobile networks.

Conclusion

This paper presents a policy based access management scheme for heterogeneous wireless networks in smart space environments. The access management system uses capacity surfaces to assess the residual capacity available in each network and determine the best network to carry the requesting service. The final paper will present results showing the load balancing and QoS performance of the proposed access management system. This paper also presents a fuzzy logic based inter-system handover initiation algorithm. The algorithm decides the time to initiate a handover request to another available access network based on QoS and pricing tariffs. The final paper will present results that show a reduction in unnecessary inter-system handover requests when compared with a threshold approach and a handover controller that continually strives to be connected to the cheapest network.

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