

## Network Access and Handover Control in Heterogeneous Wireless Networks for Smart Space Environments

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### Abstract

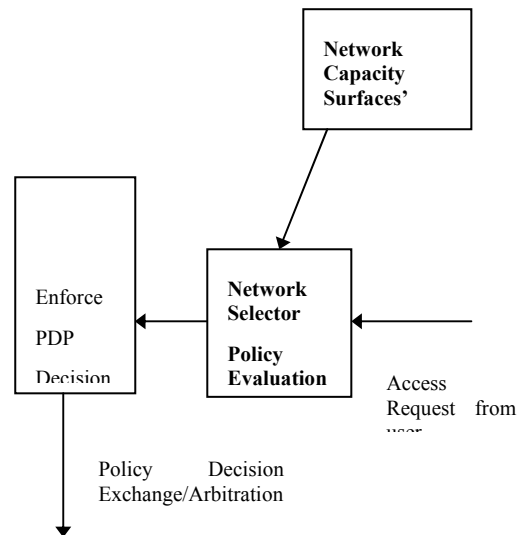
*Future smart environments will feature multiple radio access technologies that need to seamlessly integrate to form a heterogeneous wireless access network. On the arrival of a service request from a smart space user, the network must assign one of the available access networks based on either operator policies or user preferences or a combination of both. Selecting the most optimal network from those available and controlling network access is an important consideration for overall network stability and QoS provisioning. In this paper we propose a policy based management system to control network access and a fuzzy logic based inter-system handover decision algorithm for future heterogeneous wireless networks. A call admission policy allocates a network to a service request based on the current load and service mix in each available network, while the fuzzy logic controller focuses on inter-system handover initiation so as to maintain satisfactory QoS to the end user.*

### 1. 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]. The motivation for heterogeneous wireless networks arises from the fact that no one technology or service can provide ubiquitous coverage and continuous high QoS levels across multiple smart spaces, e.g. home, office, public smart spaces, etc. 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 802.11a/b WLAN, and other technologies yet to be developed, 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 [2]. 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.

Admission control is responsible for making access decisions in response to a user's access request based on a range of criteria including required QoS, bandwidth requirement, coverage, cost etc. From a network operator's perspective, admission control facilitates high capacity and spectrum efficient usage. This can be achieved through load balancing between the available access networks and enforcing inter-system handovers to meet changing QoS constraints. Sophisticated admission control schemes are required to maintain QoS contracts and continuous connectivity in an environment where users are dynamically roaming between different access technologies [3]. A plethora of access control schemes have been proposed for call admission control in wireless networks that exhibit soft



**Figure 1:** Policy Based Access Management

capacity such as those based on CDMA technology [4,5,6,7,8]. All of the proposed schemes are based on a homogeneous network environment and do not consider the possibility of initiating a handover for session transfer to another available access network. Access control in heterogeneous wireless network environments based on parameters such as radio channel characteristics, resource availability, QoS constraints, user and operator preferences, remains an open issue.

After a network is allocated to a requesting user, the QoS offered to that user must be monitored so that QoS contracts are maintained. At a particular point during the lifetime of the session, an inter-system handover may be required. The handover may be initiated for a number of reasons, including, reduced QoS, user experiencing bad QoS for a specific length of time, a cheaper access network has become available etc. Choosing the correct time to trigger a handover request based on such parameters is crucial as an unnecessary intersystem handover, which is associated with a significant signalling load, can waste resource, reduces QoS temporarily, and can lead to a volatile system state. To make efficient use of the available resources throughout a heterogeneous wireless network, an effective time decision algorithm is required to choose the most optimal time, if any, to trigger a handover request based on user/network operator preferences.

This work investigates the use of policy based management to control network access and the assignment of the most optimal network on a call-by-call basis while fuzzy logic control techniques are used to trigger inter-system handover requests based on perceived QoS, user and network operator preferences.

## 2. Policy Based Management

A policy based management system is one in which the system's operation is determined by a set of rules and instructions. Policy rules are evaluated when triggered by an event, such as the arrival of a new user into the network. The policy rules define how the network should handle such events. The outcome of the policy evaluation is a policy decision, which is enforced on a specific network device, such as an admission controller to accept or reject a new call request. Policy rules are declarative and so can be adapted at run-time to flexibly control system behaviour as network conditions change, and are therefore becoming increasingly popular in adaptive, run-time configurable networks and information systems [9]. To this end we propose a policy system architecture for making network access decisions upon the arrival of a service request. The design of systems that use policy rules that achieve business goals has to be done carefully and with a good understanding of the network's operation. Conflicting policies can cause unexpected behaviour in the network and mechanisms are available for detecting certain conflicts before deployment [9].

## 3. Network Access Control using Policy Based Management

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

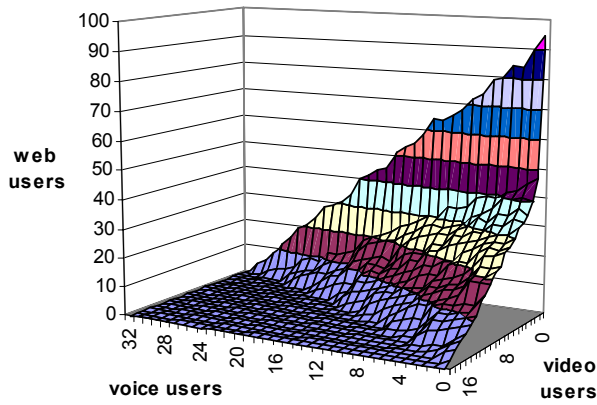


Figure 2: EDGE Capacity Surface

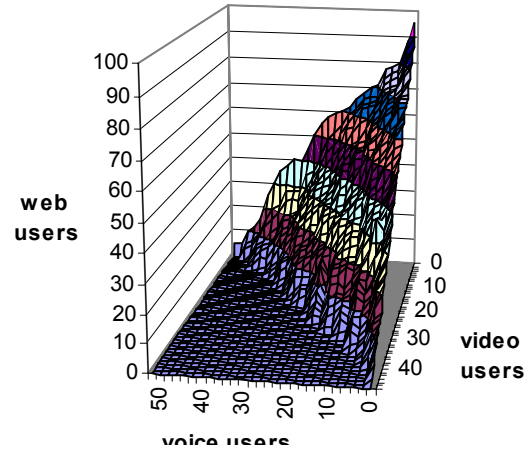


Figure 3: UMTS Capacity Surface

whether a policy decision is satisfied is taken, i.e. the Policy Decision Point (PDP). 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 a 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 new call or inter-system handover request. These access control decisions are made in the PDP, which contains the network selector. The network selector's 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 capacity surfaces' for EDGE and UMTS are shown in Figure 2 and Figure 3 respectively. The access decision from the PDP is sent to the PEP, which informs the requested

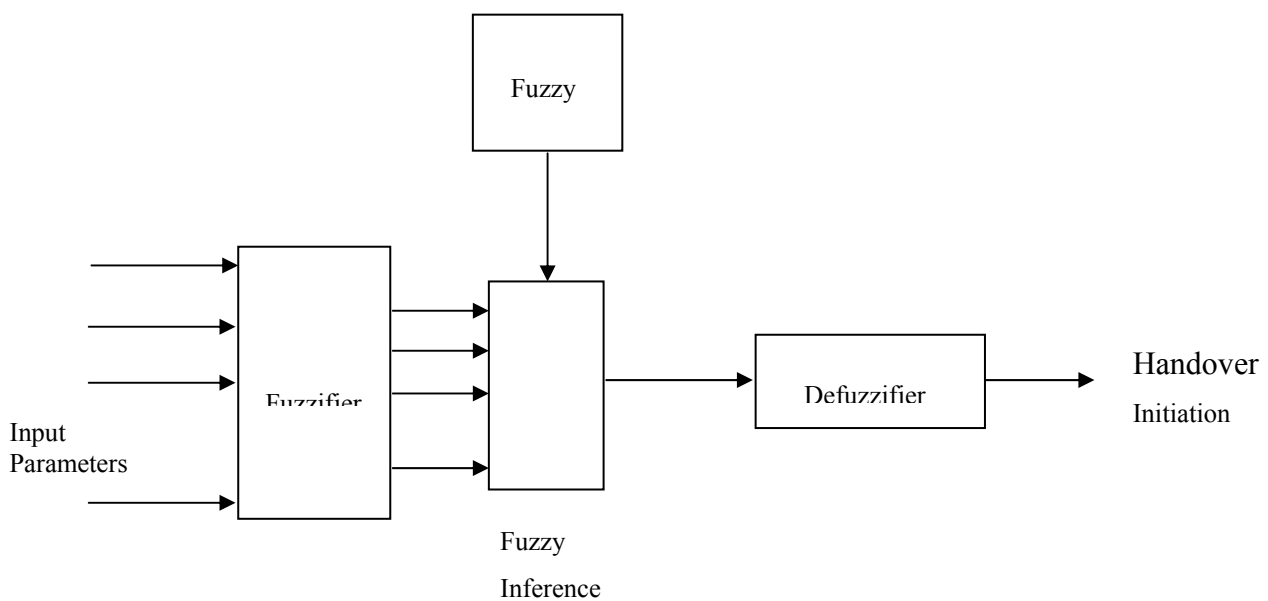


Figure 4: Fuzzy Logic Controller Architecture

mobile whether its connection request is granted and to which network it should connect. Due to knowledge of network capacity, it is expected that this network selection policy will provide a greater level of QoS to all users than simply allocating any network to a requesting user.

#### 4. Inter-system Handover Initiation using Fuzzy Logic

Several proposals exist for homogeneous networks involving horizontal handover between adjacent cells [10,11]. 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 [10]. In contrast to horizontal handover, vertical handover, which occurs between different overlaying access networks in a heterogeneous network, has a higher layer of complexity. The time allowed to process an inter-system handover request 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, the time QoS has been below the predefined threshold, data held in user profile such as the price a 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 4.

The handover parameters are applied to the fuzzifier, where they are mapped into fuzzy sets. The fuzzy sets indicate the 'goodness' of each parameter, e.g. 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

HO = Handover

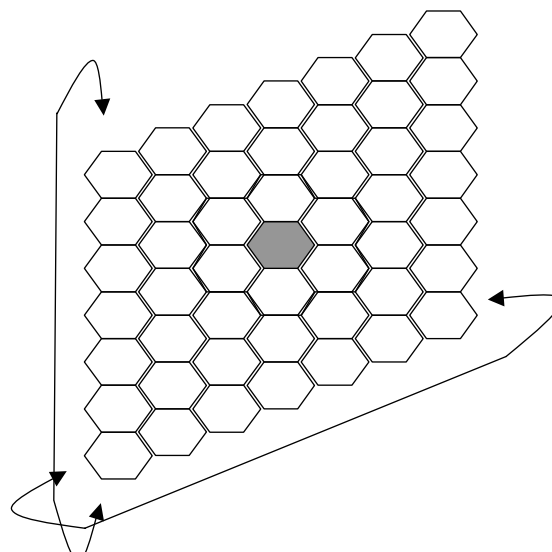


Figure 5: Cellular Model

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 [12]. The fuzzy rule base has initially been designed so that a handover will be triggered 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.

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 [12]. 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.

## 5. Simulation Model

To evaluate the proposed policy based access and inter-system mobility management system we have implemented a computer simulation model of a heterogeneous wireless access network with access technologies EDGE and UMTS. By obtaining the capacity surface of a WLAN network, the proposed scheme could be readily extended to

include WLAN access. Continuous coverage for both EDGE and UMTS are provided throughout the network with each cell containing EDGE and UMTS transceivers. We consider a 49 cellular model with wraparound in the horizontal and vertical planes as shown in Figure 5. This ensures that each cell has an equal number of neighbours for CIR measurements. Multi-modal terminals are positioned uniformly throughout the network. In this study, we consider three classes of user traffic – voice, www and video streaming, which are expected to be among the most commonly used types of service in mobile networks in the near future. Future work will consider that the service mix is likely to change with new services being created on a continuous and dynamic basis.

## 6. Simulation Results

In this section we will present some preliminary results from the network access and inter-system handover algorithms. The performance of the proposed policy based access and inter-system handover management system is assessed based on network utilisation, QoS offered to the end user and the time that a handover is triggered by the fuzzy logic controller.

### 6.1. Network Access Management

To assess the network access decisions made by the policy based management system, the network simulation is run for 3 hours and performance statistics measured at the completion of each session. We investigate two load scenarios in which 200 and 300 users are positioned uniformly throughout the network. The QoS metrics used are

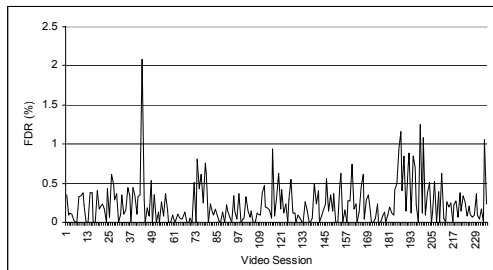
Table 1.  
Session Distribution (%)

Load Scenario	Service Type	Policy Selection	Network	Random Selection	Network
		UMTS	EDGE	UMTS	EDGE
200 Users	Voice	67	33	51	49
	Video	99.9	0.1	51	49
	Web	1.0	99	50	50
300 Users	Voice	42	58	51	49
	Video	96	4	51	49
	Web	15	85	51	49

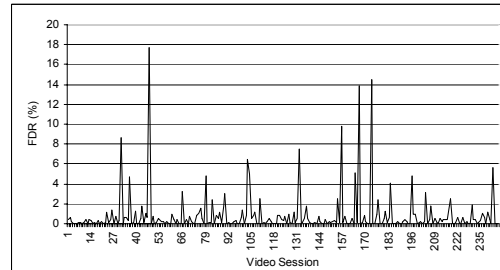
the video frame drop rate (FDR) for video streaming sessions and the block error rate (BLER) for web sessions.

The distribution of sessions between the two networks under investigation is given in Table 1 for both the policy based approach and random network selection for each load scenario under

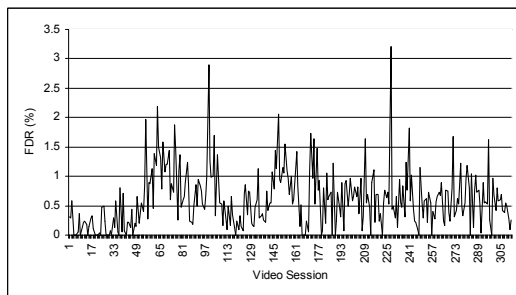
investigation. These results show how the policy access management system utilises the network capacity information from the capacity surfaces' to allocate the network that has a highest probability of providing the best QoS for each session type. The effect of load balancing sessions between the available networks is to provide each user with the



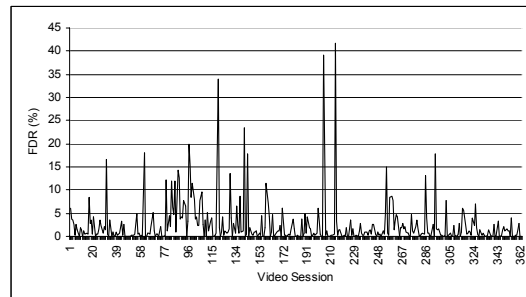
**Figure 6:** Policy Network Selection, 200 users



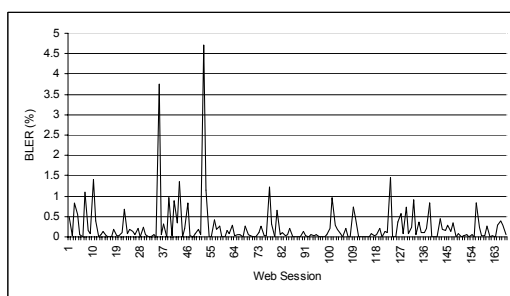
**Figure 7:** Random Network Selection, 200 users



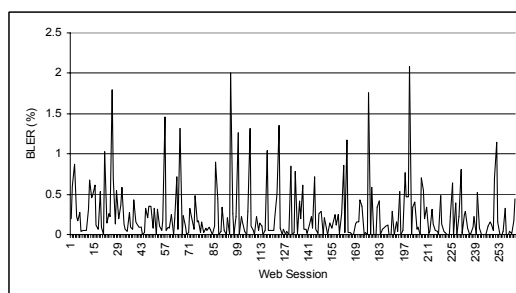
**Figure 8:** Policy Network Selection, 300 users



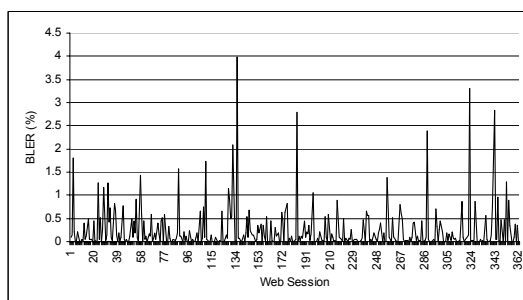
**Figure 9:** Random Network Selection, 300 users



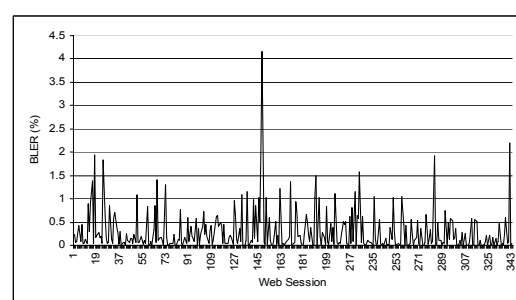
**Figure 10:** Policy Network Selection, 200 users



**Figure 11:** Random Network Selection, 200 users



**Figure 12:** Policy Network Selection, 300 users



**Figure 13:** Random Network Selection, 300 users

best possible QoS under varying network conditions. The following results are taken from QoS measurements for web and video streaming sessions at the centre cell, the shaded cell in Figure. 5. Similar results were obtained for the other cells. The FDR was used as the QoS metric for video streaming sessions. A FDR of 1% is considered acceptable for mobile video streaming sessions. The video session FDR for the policy and random network selection for each load scenario is shown in Figure 6 to Figure 9. It is observed that the QoS offered to video users using the policy based access management system far exceeds that of the random network selection procedure.

The BLER was used as the QoS metric for web sessions. High BLER in web sessions result in high packet retransmission rates, which introduce undesirable delay in web page download. We consider a BLER of 5% to produce acceptable delays due to packet retransmission. The web session BLER for the policy and random network selection are shown in Figure 10 to Figure 13. The BLER remains below the 5% threshold with both network selection schemes.

### 6.2. Inter-system Handover

The current inputs to the fuzzy logic based

handover time decision algorithm are the QoS offered to the end user (FDR, BLER), time QoS is below predefined threshold (1% FDR for video) and the number of handovers already executed for the current session. Figure 14 to Figure 17 shows the handover trigger signal for increasing number of handovers executed for a video streaming session. These results show that a handover is triggered only when deemed absolutely necessary by the fuzzy logic controller. Future work will compare the performance of our proposed scheme with that of a signal strength/QoS threshold approach. It is expected that our proposed fuzzy logic scheme will reduce the number of unnecessary handover attempts throughout the network.

### 7. Conclusion

This paper presents our current work in policy-based management and fuzzy logic control techniques for call admission and mobility management in smart environments with multiple wireless access systems. The developed techniques allow service providers offering multiple wireless network types to make optimum network selection decisions. As intersystem roaming will be common practice in future smart space environments, a fuzzy

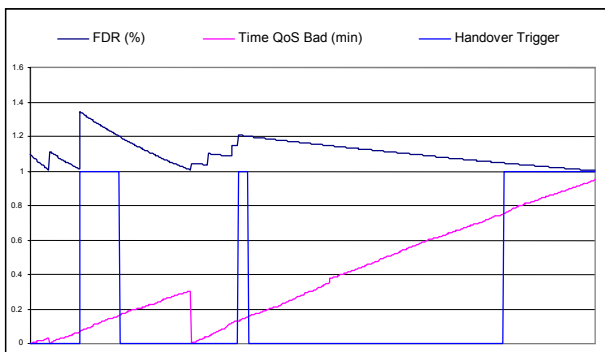


Figure 14: Four Handovers already executed

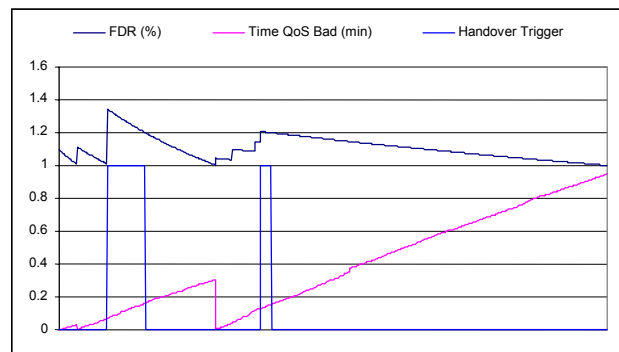


Figure 15: Six Handover already executed

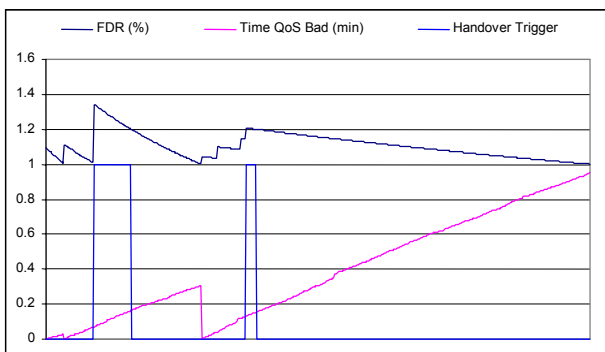


Figure 16: Eight Handovers already executed

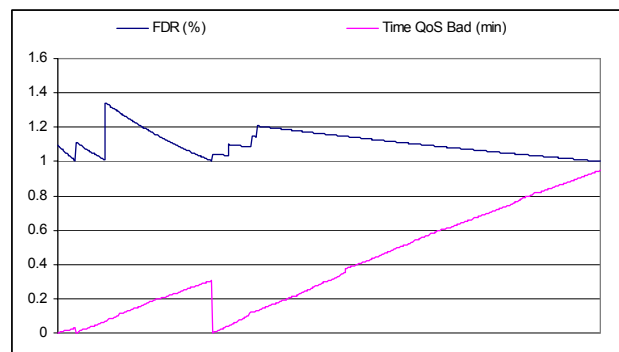


Figure 17: Ten Handovers already executed

logic based inter-system handover control scheme for seamless mobility between heterogeneous networks is proposed. For call admission control decisions, policy rules are evaluated using network load information in the form of capacity surfaces', which enable an initial evaluation of the residual capacity and expected QoS for the requested service type. The simulation model developed considers multi-modal terminals roaming between UMTS and EDGE networks, but can be extended to include any wireless network by obtaining capacity surfaces of such systems.

Results have shown the load balancing effects of policy based network access and the higher levels of QoS offered to users when allocated to a network using policy evaluation of network capacity statistics. We have also shown preliminary results of triggering handover using a fuzzy logic controller.

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