Personalised Handoff Decision for Seamless Roaming in Next Generation of Wireless Networks

Lekometsa Mokhesi
Department of Computer Science
University of Cape Town
South Africa
lmokhesi@cs.uct.ac.za

Antoine Bagula
Department of Computer Science
University of Cape Town
South Africa
bagula@cs.uct.ac.za

Abstract—**The past three decades have experienced a phenomenal emergence of several wireless networks and technologies. This next generation of wireless networks (4G) will be integrated into one IP-backbone to offer improved services to the user. The features of 4G include: wide coverage, high data rates, seamless roaming and personalisation. This paper presents a personalised handoff decision method to offer personalisation in seamless roaming for the next generation of wireless networks. This is done by assigning profiles to different users with different preferences and using these profiles to offer personalised handoff. The integration of these two important features of 4G networks will provide the end user the ability to choose their own preferred networks while they roam freely between heterogeneous networks.**

Keywords-Seamless roaming; Handoff Decision; Personalisation; Next Generation Networks;

I. Introduction

Mobile devices and wireless network technologies are evolving towards a universal wireless access computing model. This computing model will enable users to remain connected wherever they are, and have access to services with whatever terminal they use. One of the drivers for this computing model is the Fourth Generation of Wireless Communications (4G). This family of next-generation of wireless systems represents a heterogeneous networking environment with different access network technologies converging into one IP-backbone. These networks, however, differ in bandwidth, latency, cost and coverage [1].

The prospects of 4G include: Seamless roaming and personalisation. The latter refers to the method used to provide tailored services that are built on the individual preferences of users in a given context, automatically reflecting user's needs in a specific situation [4]. This user centric approach means that the applications and services in 4G will need to adapt to who the user is, the user's interests and context [10]. A contrast to this approach has proved to be less effective and costly whereby technology is built for the sake of technological advancement without the final user in mind. Consequently, the technology suffers low user adoption which may lead to financial losses as the final products do not serve the users' needs.

In 4G, personalisation usually refers to the personalised applications, services and content for the user. However in this paper we propose that personalisation can be provided as an integral part of seamless roaming which is a key feature in 4G. Seamless roaming can be achieved by integrating the disparate networks and technologies in 4G. Seamless roaming enables the user to be best connected to the appropriate network depending on their needs. The key enabler for seamless roaming is session handoff. Therefore, the paper focuses on personalised handoff for seamless roaming. Personalised seamless roaming means the user decides the type of networks they wish to roam around during their active session.

Many application layer handoff solutions divide handoff process into three steps: Handoff initiation, Handoff decision and handoff execution. Handoff initiation is the system's recognition that handoff is required. Previous handoff solutions were based on recognition of disconnection (signal strength). This may take a long time to discover hence; undermine service continuity. Secondly, these solutions do not consider any other context changes and therefore do not offer personalisation.

Handoff decision determines which network to handoff to. Handoff decision is driven by user preferences (mainly transmission cost and wireless interface power consumption), wireless environment constraints (access network availability and properties and client communication capabilities), and SLS requirements of the application [3]. Recent solutions on handoff decision provide a context aware approach to handoff decision based on multiple criteria using Multi-criteria decision making (MCDM) methods. However, these methods provide less support for user preferences and the solutions focus on specific applications i.e. QoS thus do not offer personalisation to a wide range of users.

Handoff Execution redirects the flow of data to the new wireless network interface. This process is usually transparent to the user.

A. Related work

Much of the research in 4G networks has focused on either seamless roaming or personalisation but not the integration of both. Different MCDM methods have been used in literature for handoff decision to provide seamless roaming. For

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instance, Analytical Hierarch Process (AHP) has been proposed in numerous researches including [1, 3, 8, and 11]. Other methods such as Technique for Order Preference by Similarity to Ideal Situation (TOPSIS) have been proposed in [2]. AHP and TOPSIS are limited in supporting user preferences. These methods involve building pairwise comparison matrices representing the alternatives relative to each other based on different criteria. These methods cannot model constraint criteria i.e. SLS. The SLS encodes the application requirements and does not relate to the alternative networks. The SLS can be regarded as a constraint criterion as the user can require different decisions based on the values represented by the SLS.

Furthermore, these methods only consider decision making under certainty. In wireless networking, not all context information is available at decision time. Hence, these solutions provide less support for user preferences, context propagation and hence less personalisation. BBN offer personalisation through; decision-making under certainty and uncertainty, modeling of constraints, adaptability through context propagation and allows creation of diverse user profiles depending on application type and user preferences

B. *Contribution and outline*

Handoff decision undergirds the overall handoff process. If the handoff decision does not serve the interests and preferences of the user, then it is not user centric. The user centricity of the handoff decision means the user specifies the context changes that trigger handoff and the network properties of the target network they wish to handoff to. This is based on their current context, profile and preferences. This paper presents a personalised handoff decision method for seamless roaming using a MCDM based on Bayesian Belief Networks (BBN). This method uses a profile-based approach by defining a set of profiles that represent different types of users with different needs

The structure of the paper is as follows: Section II describes the architecture that supports the personalised handoff decision. Section III provides an overview of the handoff decision using BBN. Section IV describes the personalised users profiles used to evaluate the handoff decision method. Section V provides results for the conducted experiment. Finally, section VI concludes the paper.

II. System architecture

The architecture supporting the personalised handoff decision is a distributed middleware infrastructure with components running on fixed hosts in the wired network, *proxy*, as well as on the user's mobile device, *client stub*. The Proxy is deployed on client-to-server distribution path and coordinates with the client stub for handoff decision and execution. The high level components of the system are shown in figure 1. The handoff process is primarily executed as proxy functionality.

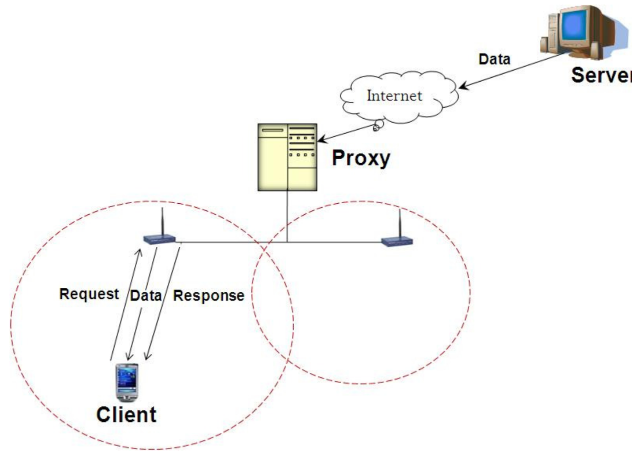

Figure 1: High Level Middleware Components

III. HANDOFF DECISION BASED ON BAYESIAN BELIEF NETWORKS

A. *Handoff Decision Bayesian Belief Network Model*

One important attribute of a handoff decision solution is the ability to incorporate user preferences. The paper uses a Bayesian Belief Network (BBN) based MCDM method for handoff decision. BBNs have been used extensively in expert and intelligent systems for their ability of knowledge representation, reasoning under uncertainty, reasoning with conflicting criteria and modelling interdependent criteria. [9] describes how to use BBN as a MCDM method for handoff decision problem. The generic Limited Memory Influence Diagram (LIMID) defines three important criteria for handoff decision: Network QoS, Service Level Specification (SLS)/Application requirement and user preferences. These criteria are synthetic criteria, hence are defined in terms of other criteria (sub-criteria). Network QoS is defined by: Bandwidth, jitter and delay. SLS is defined by: Tolerable delay, jitter and data loss. Finally, "User preferences (UP)" is defined by: network cost and interface power consumption (IPC).

B. *Differentiated Profiling on Criteria*

The paper proposes a differentiated profiling technique for the states of the synthetic criteria. All the synthetic criteria assume two values (low and high) [9]. For network QoS and SLS, a simple technique for mapping user perceived QoS to QoS parameters is used as shown in table 1. For network cost and IPC, the differentiated levels are shown in table 2. All synthetic values are deterministic from the combination of lower level attributes. For instance, the user preferences are set to high if both the cost and the IPC are high.

IV. CREATING USER PROFILES

The new concepts introduced by 4G are based on the assumption that each user wants to be considered as a distinct, valued customer who demands special treatment for his or her exclusive needs [6]. Therefore, to address this requirement,

Table 1: Service Differentiation for QoS and SLS

Parameter / Service Level	Bandwidth	Delay	Jitter	Application Type
Low	64Kbps – 512Kbps	200ms – 400ms	200ms – 400ms	WWW, SMTP
High	512Kbps	<50ms	<50ms	Video, Health

Table 2: Level Differentiation for Cost and IPC

Parameter / Level	Cost	IPC
Low	Cheap: <R2/Mb	<40w
High	Expensive: >R2/Mb	>40w

three user profiles were created for handoff decision representing three types of users with different preferences and needs. The profiles are described as follows:

Profile A (QoS Oriented) - This profile considers QoS to be the most important criteria for decision making. As a result the target network that has the highest QoS will invariably be the preferred network. This profile is applicable for users who always run critical time-sensitive and high QoS applications such as live multimedia, health and clinical applications. This profile implements a utility function that rewards state configurations that have networks with high QoS. The sample utility table representing different utility weightings for this profile is shown in table 3.

Table 3: Part of the utility table for Profile A

data = (
95 % UMTS_QoS=low Wi-Fi_QoS=high Bluetooth_QoS=low Target Network=**Wi-fi**
80 % UMTS_QoS=high Wi-Fi_QoS=low Bluetooth_QoS=low Target Network=**UMTS**
75 % UMTS_QoS=low Wi-Fi_QoS=low Bluetooth_QoS=high Target Network=**Bluetooth**
}

Profile B (Cost Oriented) - This profile on the contrary considers User Preferences (cost and IPC) to be the important criteria for decision making. This means the target network that is low in terms of cost and IPC is a preferred choice. This profile is suited for users who mostly run delay tolerant applications. Therefore, this profile implements a utility function that rewards state configurations that have networks with low"user preferences". The sample utility table representing different utility weightings for this profile is shown in table 4.

Table 4: Part of the utility table for Profile B

data = (
45 % UMTS_UP=low Wi-Fi_UP=low Bluetooth_UP =low Target Network=**Wi-Fi**
10 % UMTS_UP =high Wi-Fi_UP =low Bluetooth_UP=low Target Network=**UMTS**
95 % UMTS_UP=low Wi-Fi_UP=low Bluetooth _UP =low Target Network=**Bluetooth**
}

Profile C (SLS controlled) - This profile combines the concepts from profile A and B by introducing constraint criteria, SLS. This profile is suitable for a common user that runs different types of applications that differ in terms of time sensitivity and criticality. This user prefers a high QoS network when they are running a critical and time sensitive application and low cost network when they are running non-critical application. Profile C therefore implements a utility function that rewards state configurations that have networks with high QoS if the SLS is declared to be "high" else rewards state configurations that have networks with low user preferences if the SLS is declared to be "low". The sample utility table representing different utility weightings for this profile is shown in table 5.

Table 5: Part of the utility table for Profile C

data = (
30 % UMTS_UP=high UMTS QoS=high Wi-Fi_UP=low Wi-Fi QoS=low Bluetooth_ QoS=low Bluetooth_UP =low SLS=low Target Network=**UMTS**
85 % UMTS_UP=low UMTS QoS=low Wi-Fi_UP=low Wi-Fi_QoS=low Bluetooth_ QoS=high Bluetooth_ UP=low SLS=low Target Network=**Bluetooth**
95 % UMTS_UP=low UMTS QoS=low Wi-Fi_UP=low Wi-Fi_QoS=high Bluetooth_ QoS=high Bluetooth_ UP=low SLS=high Target Network=**Wi-Fi**
15 % UMTS_UP=low UMTS QoS=high Wi-Fi_UP=low Wi-Fi_QoS=high Bluetooth_ QoS=low Bluetooth_ UP=low SLS=high Target Network= **Bluetooth**
}

V. EMULATION AND RESULTS

The experimental handoff system was developed to demonstrate personalised handoff decision in an emulated environment. The main result is; given varying context information for each profile, whether the system can correctly decide on the target network for handoff according to the user's profile and preferences. The implementation included developing: decision engine using BBN MCDM, Context repository and two emulators. These emulators are: wireless card (3G, Bluetooth, Wi-Fi) and handoff trigger emulators. The wireless card emulator emulates the behaviour of wireless network card interface under consideration. It provides an interface similar to the real wireless card and introduces the same behaviour. The handoff trigger emulator periodically sends handoff trigger messages to the client by emulating different context changes. The emulation was implemented in Java and uses Java technologies: SUN Java Media Framework JMF) for (RTP-based video streaming. The decision engine exploits the Hugin Java API for BBN models [7].

An experiment was conducted to evaluate the personalised handoff decision. This experiment aimed to evaluate the correctness of the handoff decision in terms of network ranking under different execution environments and context changes for each of the three profiles. The BBN MCDM method uses the principle of maximum utility whereby the target network that has the highest expected utility becomes the preferred choice. Upon initialisation, the client declares the profile and SLS of the application to the proxy. The handoff triggering emulator periodically writes different context changes represented by different state configurations into the context repository.

The results for profile A are discussed below:
When all the networks have ”high” QoS, the expected utilities are: 0.5208, 0.5 and 0.4999 for Wi-Fi, UMTS and Bluetooth respectively. Wi-Fi is the preferred target network. When Wi-Fi has ”high” QoS and both UMTS and Bluetooth have “low” QoS, the expected utilities are: 0.5697, 0.0 and 0.0 for Wi-Fi, UMTS and Bluetooth respectively. Wi-Fi is the preferred network. When Bluetooth has “high” QoS and both UMTS and Wi-Fi have ”low” QoS, the expected utilities are: 0.0, 0.0 and 0.5697 for Wi-Fi, UMTS and Bluetooth respectively. Bluetooth is the preferred network. When UMTS has ”high” QoS and both Bluetooth and Wi-Fi have ”low” QoS, the expected utilities are: 0.0, 0.5697 and 0.0 for Wi-Fi, UMTS and Bluetooth respectively. UMTS is the preferred network. From the above results, the handoff decision favors networks with high QoS.

The results for profile B are discussed below:
When all the networks have ”low” ”user preferences” (meaning low cost and low IPC), the expected utilities are: 0.5001, 0.4999 and 0.5116 for Wi-Fi, UMTS and Bluetooth respectively. Bluetooth is the preferred network. When Wi-Fi has “low” user preferences and both UMTS and Bluetooth have “high” user preferences, the expected utilities are: 0.5560, 0.0 and 0.0 for Wi-Fi, UMTS and Bluetooth respectively. Wi-Fi is the preferred network. When Bluetooth has “low” user preferences and both UMTS and Wi-Fi have ”high” user preferences, the expected utilities are: 0.0, 0.0 and 0.7692 for Wi-Fi, UMTS and Bluetooth respectively. Bluetooth is the preferred network. When UMTS has ”low” user preferences and both Bluetooth and Wi-Fi have ”high” user preferences, the expected utilities are: 0.0, 0.5480 and 0.0 for Wi-Fi, UMTS and Bluetooth respectively. UMTS is the preferred network. From the above results, the handoff decision favors networks with low “user preferences” expressed in terms of cost and IPC

The results for profile C are discussed below: If the SLS is high and all the networks can provide the required QoS, the expected utilities are: 0.5466, 0.5 and 0.4999 for Wi-Fi, UMTS and Bluetooth respectively. When all networks have low QoS and the SLS is high, the expected utilities are: 0.2101, 0.0 and 0.0 for Wi-Fi, UMTS and Bluetooth respectively. If only Bluetooth has a high QoS and the SLS is high, the expected utilities are: 0.0, 0.0 and 0.5262 for Wi-Fi, UMTS and Bluetooth respectively. If the SLS is low and all networks have low ”user preferences”, the expected utilities are: 0.5099, 0.4647 and 0.5177 for Wi-Fi, UMTS and Bluetooth respectively. From the results, the network ranking is controlled by the current value of the SLS.

VI. CONCLUSION

This paper has presented a personalised handoff decision designed for seamless roaming for future generation of wireless networks. The proposed handoff decision can integrate a variety of wireless technologies (Wi-Fi, UMTS and Bluetooth) into a seamless communication environment. It uses a range of context information about networks, users and applications to perform personalised handoff decision for each profile. It implements a profile based approach that categorises different users and their needs into different profiles thus offering deep personalisation. This method provides a fine granularity to the user for deciding even the specific network they which to handover to. For instance, when all the networks meet the application's QoS requirement, the user can still specify their preferred network in such a scenario based on their own preference. The experimental results of the evaluation of context changes and the handoff decision for each profile have been presented.

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