Handover Initiation and Decision Criteria for the fourth Generation Radio-Mobile Networks

Roxana Zoican[1], Dan Galatchi[2]
[1] The Electronics and Telecommunications Faculty, POLITEHNICA University, Bucharest, ROMANIA
roxana@elcom.pub.ro
[2] The Electronics and Telecommunications Faculty, POLITEHNICA University, Bucharest, ROMANIA
dg@elcom.pub.ro

Abstract— **Despite qualms about its early success after years of promise, 2,5G and 3G technologies will show the best long-term results when it comes to wireless data access. However, 4G and Wi-Fi technologies will also grow as high-speed wireless data systems become varied and operators choose an air-interface matching the varied wants and needs of desired audiences. Digital fourth-generation IP-based high-speed cellular systems will account for 14% of total mobile and portable wireless data revenues in 2007 and 50 million subscribers by year-end 2007. Realization of seamless handovers to the best network section while considering QoS and AAAC (Authentication, Authorization, Accounting and Charging) calls not only for seamless handover protocols, but also intelligent handover decision strategies. In this paper is analyzed a handover decision strategy in mobile All-IP networks to support seamless handover scenarios.**

Index Terms—**mobile-assisted handovers, mobile-controlled handovers, handover latency**

I. INTRODUCTION

Today's mobile communication systems are designed as logically separate networks. They are primarily designed to provide cost efficient wide area coverage for a rather limited number of users with moderate bandwidth demands (voice + low rate data). The consumer of telecommunication services of tomorrow will expect to receive the same services in a wireless fashion as he receives from a fixed network. These services require (at least instantaneously) high bandwidths. It is not expected that future users are willing to sacrifice functionality for the added value of mobility – mainly because he will hardly be using any other stationary telecommunication devices. A wireless system should therefore be transparent to the user and thus highly integrated with the fixed network. Personal wireless devices should by nature be small and consume a minimum of power. Third generation mobile systems such as UMTS and FPLMTS aim at only partially solving these problems. By mainly extended second generation technologies higher data rates, up to 2Mbit/s are offered but only to a limited number of users at the time and only in certain areas. In rural area only marginally higher bandwidth will be provided.

It is widely believed that IP will be the final means to integrate access networks of all technologies, wireless or wired in fourth generation (4G) mobile networks. The migration from traditional circuit switched networks towards a packet based wireless heterogeneous IP networks provides users great flexibility in choosing services, and also provokes a big pressure in both the network and mobile terminal design.

Mobile end-systems are equipped with interfaces of W-CDMA (UMTS-TDD), WLAN (802.11b), and fixed networks (Ethernet). Access routers provide interfaces between the wireless and the wired core-net-work, and are enriched with enhanced IP capabilities. Network management servers are in the fixed network used for mobility management, QoS, security and paging issues, such as AAAC servers, QoS brokers, and Paging agents. The whole architecture is based on IPv6 exploiting all IPv6 specific support for IP based mobility management. Fast Handovers with some enhancements and context transfer techniques are used to provide seamless handovers. To provide QoS, the DiffServ model is adopted because of its high scalability and reduced signaling overhead.

The DiffServ model for QoS was developed to diferentiate IP traffic so that the traffic's relative priority could be determined on a per-hop basis. By using DiffServ, traffic is classified based on priority. Then the traffic is forwarded using one of three IETF defined Per-Hop Behavior (PHB) mechanisms. This approach allows traffic with similar service characteristics to be passed with similar traffic guarantees across multiple networks, even if the multiple networks don't provide the same service the same way. This is an important feature because the Internet is really a network of multiple service provider networks. The association of DiffServ principles with the use of QoS Brokers controlling a QoS domain provides a large-scale support for QoS.

A user profile stipulating various classes of services provided in different administrative domains and corresponding service prices are stored in the user's home network. Real-time services with quality comparable to traditional cellular networks should be generally accessible regardless of the technology and the access network and uninterrupted during a handover. Such a heterogeneous system poses challenges in the handover design. These challenges come from the integration of the seamless handover with QoS support in an IP network while considering AAAC, and becomes more complicated if a potential large number of candidate networks are considered. This paper aims to design a handover decision strategy, that does not only provide users with the optimal network with minimum influence on the application, but also efficiently uses network resources.

II. THE MAIN TYPES OF HANDOVER

Mobile-assisted handovers are used in 2G and 3G wireless networks, where mobile terminals send the measurement report to the network, and the network makes the handover decision. Handovers are usually carried out within an administrative domain, considering only one technology, and work efficiently in circuit switched networks. However, in IP-based heterogeneous networks, mobile-assisted handovers have some disadvantages.

Mobile-assisted handovers have disadvantages in case of inter-domain handovers. In principle, a Security Association (SA) is required between the communication partners in IP networks. This SA can be taken for granted within an administrative domain, but to establish it between different domains is not a trivial issue. Even if security associations between domains are established, the service profiles of a mobile user indicating the subscribed services can be different in different administrative domains. E.g. a user can have a certain service of premium class in domain A, but it does not entitle him to have the same service in domain B. When a handover is required between domains, the AAA information is usually not valid in the new domain and has to be refreshed from the home network of the user, which will complicate the overall signaling design and increase the handover latency. The technical difficulties also arise from the increased complexity in network entities if numerous handover decision criteria with divergent user preferences have to be considered. Mobile-assisted handovers also have operational difficulties. In order to find an optimal network for a user, user preferences have to be considered, such as service prices in different domains and personal preferences. User preferences need to be sent to the network by signaling over the air, which increases the signaling overhead in the air, and also induces latency. Moreover, a user may be unwilling to disclose such information to the network, and potentially does not trust the current network to find a cheaper network from its competitors. In addition, the competition between service providers may prevent a service provider from giving the business away to its competitors.

In this paper, there were considered only mobile-controlled handovers, i.e. the mobile conducts the initiation and control of a handover. This strategy is more flexible and reduces the overall complexity in the network. However, mobile-controlled handovers require networks to disclose some network capability information to mobile terminals in order to choose optimal networks. Information such as bandwidth and capabilities to support certain services is transparent to mobile users in 2G and 3G net-works.

Handovers in 4G mobile networks are not only carried out in order to maintain a connection, but also to provide users better services and to meet individual requirements. A mobile terminal should make a handover decision based on user preferences automatically, and also allow a user to manually intercept the handover decision if desired.

In principle, handovers can be categorized as imperative and alternative handovers according to initiation reasons. Handovers due to low link quality are imperative, because both the handover decision and execution have to be done fast in order to keep on-going connections. Primarily, the Received Signal Strength (RSS) measured from the access point and neighboring access points are used for handover decisions, other criteria are also used, such as Carrier to Interference Ratio (CIR), Signal-to- Interference Ratio (SIR), Bit Error Rate (BER), etc.

Handovers, which are used to provide a user with better performance or to meet a particular preference, can be considered as alternative handovers. These handovers can tolerate longer handover latency, and can be sub-divided into QoS related handovers, and AAA related handovers. E.g., a user might require more bandwidth to speed up a data transfer, or need a cheaper network to reduce the service cost.

Based on the duration of the validity of the information, these criteria can be further sub-divided into static and dynamic information. E.g., AAA information, such as the network domain, user service profile in a network and business model can be considered as static, which can be buffered or acquired before the handover. However, QoS information, such as the SNR, BER and the available bandwidth are very dynamic, and have to be updated continually, which implies hard timely constraints on signaling.

In order to make a handover decision that meets the respective handover requirements, certain information from candidate networks have to be retrieved. There are many criteria that can be used for handover decisions. Usually, it makes sense to combine one or more criteria for handover decisions. Therefore, in this paper, we consider the RSS/SIR, the available bandwidth, and the user profile for handover decisions. Moreover, application requirements play an important role in handover decisions, e.g., handovers for real time or high priority services need to be made seamless, which can only be supported within a domain or between different technologies.

III. HANDOVER DECISION STRATEGY

In this section, it is described a new handover decision strategy, whose key point is to obtain the candidate networks information.

In 2G and 3G networks, handover measurements are controlled by the network. In UMTS system, prior to handover decisions, neighboring cell parameters, such as frequencies and scrambling codes, which are needed for the quick determination of neighboring cells, are sent to the mobile terminal.

It is analyzed the following pre-selection scenario: After the authentication of a user, the local AAA server sends the user a neighboring cell list including physical parameters, administrative domains, cell identifiers, IP addresses and IP prefixes. With these parameters, the user can easily measure the neighboring cells upon a handover request, and configure Care-of-Addresses (CoAs) for Mobile IP if needed. The list can be sent as a value-added location based service provided by the UMTS system to assist seamless handovers. If the size of the list is too large for cellular systems, it can be divided into small packets and transmitted after the registration process within a certain period of time. This is based on the assumption that a mobile user might not request a handover right after the registration. Alternatively, only the list of neighboring cells in the immediate adjacent of a user is sent upon registration based on the location information, and it is refreshed when the user moves to a new location.

The advantage of this scenario is that it saves the uplink signaling from handover measurements. In the downlink, clearly, the more handovers requested by the users, the higher benefit in saving the bandwidth this scenario has. Mobile users can also easily authenticate cells during the measurement process and filter out the cells, which do not belong to their service providers. This is very important in finding access points, which are operating in the free frequency bands.

Here, an example is given showing how the pre-selection is accomplished based on handover requirements and the neighboring cell list, which results in a significant reduction in the amount of the candidate networks to be measured. Suppose a mobile user has service contracts with three service providers: A, B and C, each providing the user with certain kinds of services from WCDMA and WLAN cells with different prices. The service profile and security association between the service providers are shown in Table 1, which is available in the home network and also stored in the mobile terminal.

Assume that in a certain area, each provider has two WCDMA cells and two WLAN cells denoted as AC1, AC2, BC1, BC2, CC1, CC2, AL1, AL2, BL1, BL2, CL1, and CL2. If the mobile user is moving out from the cell BC1 with an on-going voice call, an imperative seamless handover from BC1 to other cells has to be made. Usually it does not make sense to handover to a WLAN cell to continue a connection, so in the final selection, only B2 and C1 and C2 are suitable. If the user has a streaming video application in BC1 and is looking for a cheaper network, a seamless handover is also needed. Considering the allowed service and the price, only A, BL1 and BL2 are applicable, furthermore, cells from A are eliminated because seamless handovers are not possible. The selection results are listed in Table 2.

Table 1

Provider	Services	Price	Security
A	voice, video	low	no
B	voice, video	medium	C
C	voice	high	B

Table 2

Provider	Services	Price	Security
voice	A,B,C	not considered	B2, C1, C2
video	A,B	A, BL1, BL2	BL1, BL2

IV. Handovers In WLAN

A short latency in the handover decision is beneficial in handovers from a cell in the cellular network to a WLAN cell and also the other way round, in order to take advantage of the large bandwidth and the expected low price in WLAN, and also to avoid dropping a connection. The handover decision in WLAN is based on the received signal strength (RSS) of beacons from the access points, which necessitate a thorough understanding of the characteristics of the RSS of WLAN beacons. Measurements of the RSS of beacons show that the RSS has dramatic variations from the average value. Based on the theoretical analysis and corroborated by the measurement data, the RSS variation from average power can be modeled as correlated Gamma random variables. A new handover decision algorithm is designed based on Linear Regression, which is a statistical method often used to make predictions about a signal value from sample data. When the RSS from the current access point drops below a threshold, the linear regression is started to calculate the trend of the RSS for both the current and new access points for a minimum time T. The handover is made when the predicted RSS of the new access point is greater than that of the old access point over a hysteresis margin. Simulations of simple direct movements with constant speed have been carried out for the gentle path loss environment and the movement around a corner. The handover decision using the regression algorithm are compared with decisions using the traditional hysteresis algorithm. To avoid inaccurate decision using the traditional hysteresis algorithm, moving average from previous sample data received within time T and a first-order low-pass filer with the weighting factor b are used to remove the rapid variation in the RSS. A handover is successful if it is only executed once during a movement, and only handovers with success probability greater than 99% are considered. The handover decision latency relative to the theoretical handover time in the gentle path loss environment is plotted in Figure 1 and Figure 2 which show that the regression algorithm requires less decision time than the hysteresis algorithm using moving average and first-order low-pass filter. However, for handovers around a corner, the hysteresis algorithm with first-order low-pass filter is preferred, because it has low latency compared with the moving average and the regression algorithm.

The combination of the regression algorithm and the algorithm using the first-order low-pass filer with hysteresis margin can be used for WLAN handovers. A handover is carried out when either of the algorithms indicates that a handover is necessary, which can reduce handover latency in the gentle path loss environment and also avoid dropping a connection when a mobile user moves around a corner.

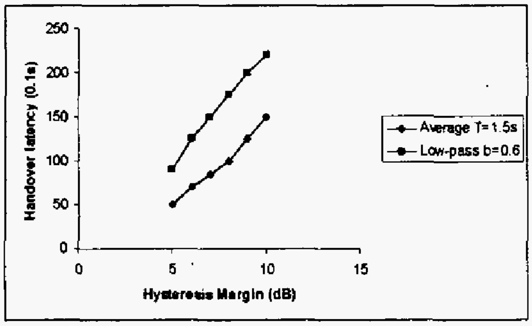

Figure 1 Handover latency using the hysteresis algorithm

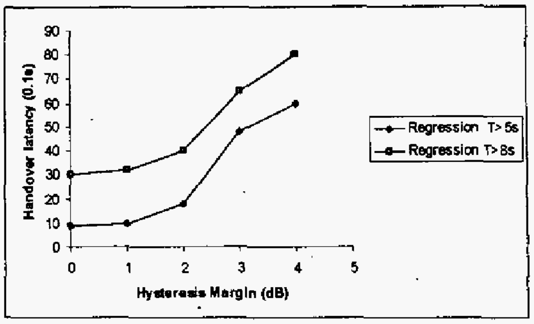

Figure 2 Handover latency using the regression algorithm

V. CONCLUSION

This paper outlines a handover strategy for 4G wireless networks. Handovers are classified as imperative and alternative handovers, and decision criteria are classified as static and dynamic information. Pre-selection of candidate networks can significantly reduce the number of networks to be measured. Acquiring candidate network capability information can be carried out with the help of L2 broadcast, which simplify the signaling. In the end, a new handover algorithm using the linear regression is presented in order to reduce the handover latency in WLAN.

REFERENCES

[1] Harri Holma, Antti Toskala, "WCDMA for UMTS," John Wiley&Sons, Ltd., 2001.

[2] P. Chan, et. al. "Mobilty Management Incorporating Fuzzy Logic for a Heterogeneous IP Environment," IEEE Communication Magazine, Dec. 2001.

[3] Zhang W. "Modeling of WLAN Beacon Signal Strength Measured in an Indoor Environment," Internal report, IKR, University of Stuttgart, 2003.

[4] W.Zhang, J.Jaehnert, K.Dolzer, "Design and Evaluation of a Handover Decision Strategy for 4th Generation Mobile Networks", IEEE.Trans.on Veh. Technol. vol.42, no.5, 2003