A Handover Optimisation Scheme in Cellular Networks

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Abstract—**The third wireless generation network will be broadband and able to support services with lots of restraints like transit delay for real time applications or cell loss probabilities.The critical period in a cellular communication is the handoff execution, because data may be lost, and the connection may be lost if there is no bandwidth available in the target cell. Most research mainly focuses on bandwidth allocation problems in radio interface, and neglects the effect of mobility in the fixed part of the network. In this article we study the effect of handovers in the fixed part of a cellular network by defining two new algorithms. These algorithms are based on two different schemes: pre-establishment with prediction and uniform pre-establishment. Their goal is to improve two parameters of the quality of service: blocking calls and dropping handovers.**

Keywords—**QoS, bandwidth, rerouting, handover.**

I. Introduction

With the growing number of mobile users during the last decade (from several millions in 1989 to several thousands of million in 2000) and the emergence of new multimedia applications such as network games or peer-to-peer sharing applications over the Internet, there is actually an absolute necessity toward the deployment of a new generation of broadband wireless network, namely the UMTS networks. Since the lack of radio resources is the main problem in wireless networks, the first proposal of the UMTS standardization committee to increase the capacity of these networks was the allocation of more frequencies for UMTS networks. Moreover, new coding techniques based on CDMA have been proposed, and some researchers suggested the use of new Dynamic Channel Assignment schemes combined with adapted power control algorithms. Other studies aim at adapting well-known scheduling techniques, such as WFQ (Waited Fair Queuing) [5], [8], to wireless environments in order to optimize the use of the bandwidth in the radio interface. Thus, most of ongoing researches deal with the optimization of the radio bandwidth in the wireless part of the network, and neglect the effect of mobility on the fixed part. In fact, many researchers claim that the wired part will offer more bandwidth than in the wireless part of the network and therefore there is no problem in the fixed part of the mobile network. Although, they usually suppose only best-effort services, or only one type of guaranteed service, which is generally the voice traffic. Nevertheless, in multi-service wireless networks, such as UMTS ones, QoS should be guaranteed at least for customers that accept to pay more in order to obtain a best-quality transmission. However, many questions have to be solved, and especially how to guarantee the QoS for some classes of traffic. QoS guarantee in multi-service networks is a very difficult problem that has been widely investigated during the last years within the ATM context. Nowadays, it is under intense researches with the new generation of the Internet. Supporting different services with various time needs makes the guarantee of QoS very difficult to achieve. For example, real-time multimedia applications require a constraint on the end-to-end data transmission time, while data transfers, such as FTP, need a minimum guarantee on packet losses. The problem of QoS guarantee is made considerably more complicate for routing especially with mobile receivers. In fact, when a mobile changes his location cell, the quality of service that was negotiated in the first path may not be maintained in a new path because of a lack of resources. Hence, many studies propose algorithms to improve the QoS on the wireless part of mobile networks.

Few researchers investigate the effect of mobility on the wired part of the network. However, during a handover and even with a high bandwidth, some data may be lost or delayed on the fixed part of the network because of the latency required by the handover procedure. This could decrease the QoS of some connections. Thus, in this paper we propose two handover algorithms that aim at maintaining a connection in the fixed part of the network for real time applications when a mobile crosses cells. The first algorithm, called Uniform Pre-establishment Algorithm (UPA), pre-establishes paths uniformly in all the neighboring clusters of the current position of the mobile.

The second one called, Pre-establishment Algorithm with Prediction(PAP), pre-establishes paths in the neighboring clusters located on the highly probabilitstic directions potentially used by the mobile.

This paper is organized as follows: Section II describes both UPA and PAP algorithms. Section III presents simulations scenarios and performance results are commented. Finally, section IV concludes the article and open the discussion on future prospects.

II. Pre-establishment Algorithms

The handover procedure in wireless networks should allow users to move without dropping their communications[4]. Two types of handover procedures are defined. An intra-zone handover occurs when a mobile enters into a cell that belongs to the same cluster (ie cell managed by the same switch as the previous one, cf Fig. 1).

In this case, a simple update of the Virtual Channel Identifier in the routing table of the switch is required in order to switch the connection between adjacent cells.

An inter-zone handover appears when a mobile moves to another cluster (cf Fig. 2). In this case, one of these two solutions may be chosen: Re-establishing or rerouting the connection.

The re-establishing method implies the interruption of the call between the source and the previous switch, in a first stage, and then the execution of a new setup connection procedure in order to re-establish the connection between the sender and the new switch. This solution is not suitable in an environment with a high-mobility degree or in a network that enables multiple connections per mobile [2]. Moreover, re-establishing multiple user connections significantly increases the connection setup overhead, the delay and the blocking probability. Rerouting is a more appealing method that avoids the interruption of communications by using reservation policies like uniform pre-establishing or pre-establishing with prediction. In the following, UPA algorithm based on a uniform pre-establishing policy and PAP algorithm based on pre-establishing with prediction policy are presented.

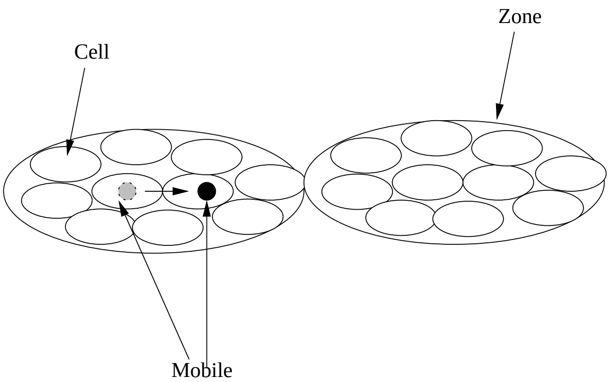

Fig. 1. *Intra-Zone Handover*.

A. Uniform Pre-establishing Algorithm (UPA)

The uniform pre-establishing scheme uses the tree connection concept that establishes point to multipoint connections for regular user.

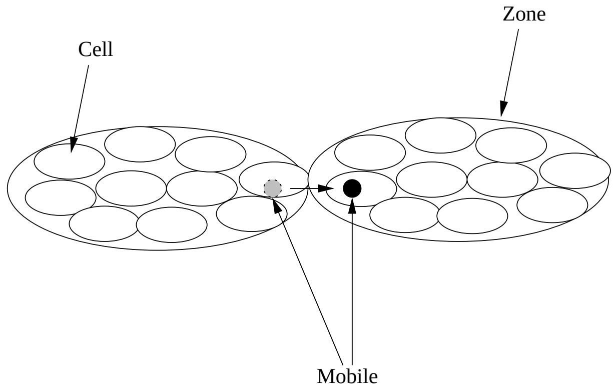

Fig. 2. *Inter-Zone Handover*.

Rerouting is immediately accomplished when a handoff occurs. Paths are pre-established between a connection tree root and each base station.

A setup rerouting table and VCIs are pre-calculated and the mobile user can exploit only a single connection and other connections are remaining available.

Several studies like VCT [1], SRMC [6] and MVC [7] are using this concept. The pre-establishment approach is a simple but efficient method to manage high mobility, and it can be applied either to local and wide area networks or in an environment with high or low mobility. The drawback of this method resides in its high consumption of bandwidth, as the VCT must be reserved in each tree for a unique connection. Like VCT, SRMC and MVC methods, UPA uses a uniform pre-establishment. It uses the same technique as VCT to find the root of the connection tree, and the same principle as MVC to establish connections towards immediate neighbor switches instead of neighbor cells.

As soon as a new connection is established, a tree of virtual connections consisting in a root and some leaves is built. The root is selected at the beginning and the switch (gateway) often links the mobile network to the fixed network. A leaves represents a neighbor switche of the current switch. When the first call occurs, UPA [3] pre-establishes paths between the root and neighbouring switches. A minimal recovery tree is built. Paths belonging to this tree are calculated according to an algorithm of shorter path which associates the bandwidth available on the links to weights. Once the bandwidth has been reserved, a specific algorithm is used whether it is a new call or a handover. For new calls, the algorithm checks if there is sufficient bandwidth. If so, the call is accepted; if not the call is rejected. As regards to handovers, the algorithm first checks the type of handover. If it is an intra-zone handover, the algorithm carries out a procedure to change the tables of commutations and output ports. In case of inter-zone handover, the algorithm proceeds with reservations in the neighboring switches of the candidate zones (cf Fig. 3) and releases the reservations in switches which are not any more adjacent to the new switch.

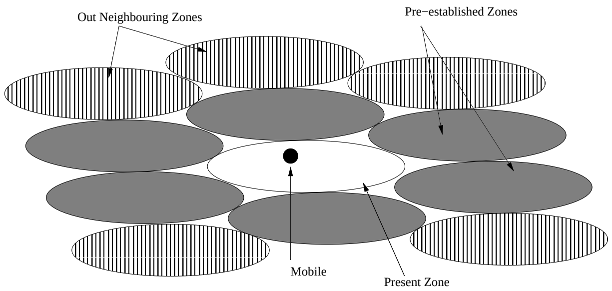

Fig. 3. *UPA Pre-Establishing.*

B. *Pre-establishing Algorithm with Prediction (PAP)*

In wireless networks, the traffic moves according to the local topology like the presence of highways, streets, roads etc. As a consequence, mobile terminals do not move randomly. In most cases, they follow predictable trajectories. For example, a mobile traveling on a street follows it and is not likely to change direction randomly. Therefore, it is possible to predict the motion of a mobile in a particular area with a hight degree of accuracy thanks to the observation of the mobility pattern in this area.
The PAP scheme will use these characteristics in order to pre-establish paths. Let $N(i)$ denotes the set of switch i neighbors. Each switch i is given a set of numbers Pij which denote the probability that a given mobile goes from switch number i to switch number j. These probabilities could be calculated off line by observing the mobile motion.

Each switch has several set of Pij. A set of Pij is associated to a specific period of time, as trajectories may change during the day. When a call enters a new switch, the PAP algorithm pre-establishes a path in each element j of $N(i)$ if Pij is bigger than a threshold T. In this way, PAP reserves paths in the most used directions (cf Fig. 4).

III. Performance Evaluation

A. *Model Description*

The proposed algorithms has been simulated in a mobile wireless system with radio cell having different traffic characteristics: different new call arrival rates and non-uniform transition probabilities. A nine-zone cluster configuration was chosen. Figures 5 and 6 respectively show the fixed and the radio part of the network. This topology consists in the following elements:

- 9 switches (zones).

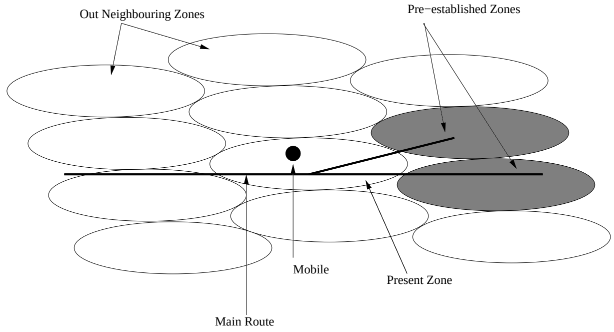

Fig. 4. *PAP Pre-Establishing.*

- Each switch manages 12 base stations (cells).
- Each cell has 32 channels and 64-Kbits/s per channel.
- Switches are connected using 18 links with 30-Mbits/s per link.

In this paper, classical assumptions are made. We assume that for each time period the traffic is characterized by the transition probabilities of switch/switch handoff calls. The arrival process of new calls is assumed to be Poisson with parameter λ_i for cell i. The call duration and the sojourn time of mobiles within a given cell are supposed to be distributed according to a negative exponential law with parameters μ_s=1/120s and μ_c=1/120s.

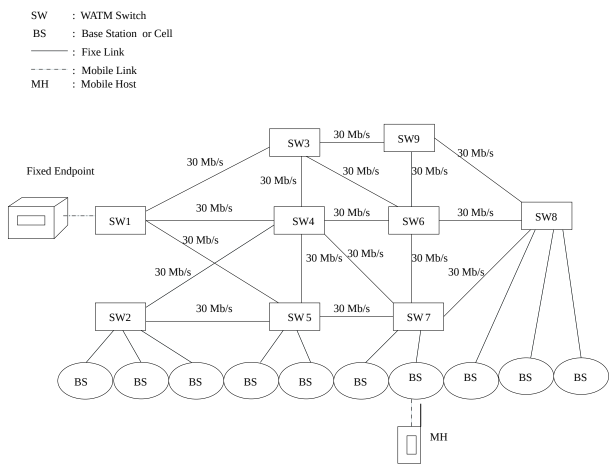

Fig. 5. *Interface Mobile.*

We were interested in the down link traffic in the direction network towards the mobile. For that, it is assumed that switch SW1 is the root of the virtual connection tree and that fixed sources are related to root SW1.

B. *Numerical Results*

Discrete event simulations have been carried out and two significant performance criteria were calculated : new call

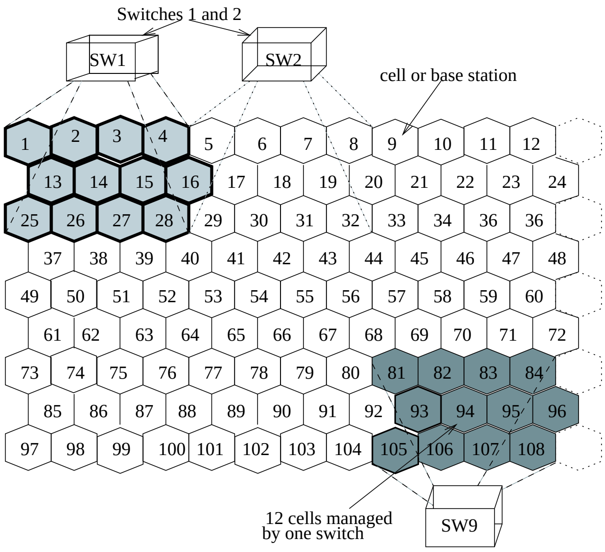

Fig. 6. *Interface Radio*.

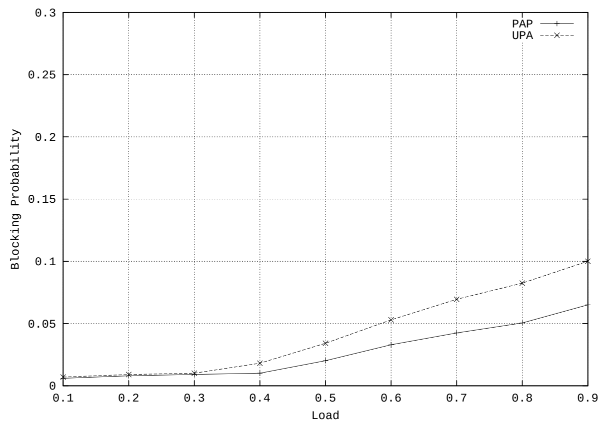

Fig. 7. *Call Blocking Probability*.

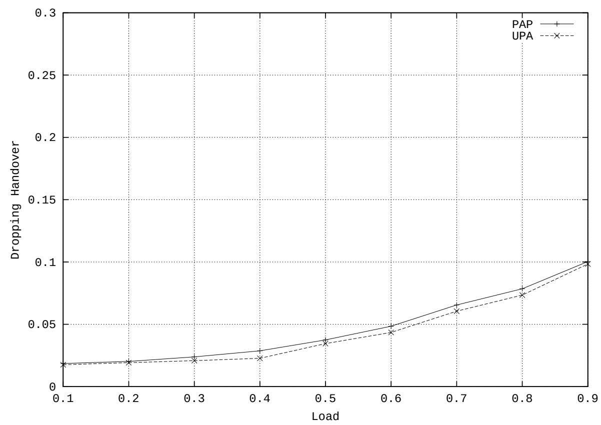

Fig. 8. *Dropping Handover Probability*.

blocking and handoff dropping. These measurements were made according to the load of the network. This load represents the bandwidth utilization of the links of the fixed part of the network. Relative confidence intervals for our simulations varied from 6% to 10%.

Figure 7 represents the new-call blocking probability. Simulation results show that our PAP algorithm improves the rate of blocking calls. Improvement can vary from 15% for weak loads up to 25% for strong loads.

The curve of figure 8 represents the probability of dropping handovers. Simulation results show that UPA and PAP algorithms are almost identical.

In the case of new calls, when the network is slightly loaded, performance for both algorithms are similar. However, when the load of the network is more important, PAP provides better performance than UAP. This is understandable while taking into consideration that the pre-establishment is made according to the local topology, ie according to the real movements of observed mobiles. UAP reserves in all directions which results in a very high consumption of the bandwidth compared to the effective need. In the case of handoffs (see Fig. 8), performance for both algorithms are similar with a little advantage for UAP. This may be understood considering that UAP garantees a connection whatever the direction and PAP reserves only in probabilitic directions: some mobiles may not follow predicted trajectories.

IV. Conclusion

This paper shows that if some cluster-to-cluster handoff probabilities are known, even approximately, it is possible to use them in order to manage the bandwidth efficiently. Indeed, if the destination of mobiles is approximately known, it may be interesting to reserve resources which are freed when the flow decreases at the end of a communication for example.

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