Wireless Networks 8, 73–84, 2002

Cell Identification Codes for Tracking Mobile Users

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Abstract. The minimization of the wireless cost of tracking mobile users is a crucial issue in wireless networks. Some of the previous strategies addressing this issue leave an open gap, by requiring the use of information that is not generally available to the user (for example, the distance traveled by the user). For this reason, both the implementation of some of these strategies and the performance comparison to existing strategies is not clear. In this work we propose to close this gap by the use of *Cell Identification Codes* (CIC) for tracking mobile users. Each cell periodically broadcasts a short message which identifies the cell and its orientation relatively to other cells in the network. This information is used by the users to efficiently update their location. We propose several cell identification encoding schemes, which are used to implement different tracking strategies, and analyze the amount of information required by each tracking strategy. One of our major results is that there is no need to transmit a code which is unique for each cell. For example, a 3 bits CIC is sufficient to implement a distance-based tracking strategy in a two-dimensional system. In addition, we propose a combination of timer and movement tracking strategy, based on either a one-bit or a two-bit CIC, depending on system topology and user mobility. An important property of our framework is that the *overall* performance cost, and hence its comparison to existing methods, is evaluated for each tracking strategy. The CIC-based strategies are shown to outperform the geographic-based method currently used in existing networks, and the timer-based method, over a wide range of parameters. Moreover, this superiority increases as the number of users per cell increases.

Keywords: PCS, wireless, mobile, user tracking

1. Introduction

The increasing demand for personal communication services (PCS) will require future wireless networks to gracefully accommodate mobility of both users and services. Contrary to the wired networks, in which user location is fixed, in wireless networks a user can potentially be located anywhere within the system service area. As the number of mobile users keeps increasing, the amount of signaling traffic required for location management keeps growing. The cost associated with the need to locate a mobile user is composed of two parts: (1) the cost of accessing data bases, such as Home Location Register (HLR) and Visitor Location Register (VLR), and (2) the cost of radio signaling over the control channel. The issue considered in this study is the utilization of the *wireless* resources associated with tracking.

Existing cellular systems use the following tracking strategy, known as the geographic-based strategy. The geographic area is partitioned into *location areas*, based on the commercial licenses granted to the operating companies. A location area (LA) is a group of cells, referred to as a home-system. The term *location area* is used by GSM systems, while IS-41 refers to the LA as *registration area*. Users register whenever they change LA, while within the LA they never register. The implementation of the geographic-based (GB) strategy is very simple: all base stations within the same LA periodically broadcast the ID of the LA. Each user compares its last LA ID with the current ID, and transmits a registration message whenever the ID changes. Hence, the user is not aware of its exact location within the LA. When there is an incoming call directed to a user, all the cells within its current LA are paged. Since the number of cells within a typical LA is very large, the tracking cost associated with the GB strategy is very high. *Hence, there is a need to provide more accurate location information to the users.*

In this paper we propose a new approach for providing the users with location information, or other related information, necessary to reduce the wireless cost of tracking. The basic idea is to use (in addition to the LA ID) a *Cell Identification Code* (CIC), which identifies the cells and their relative orientation. Each cell periodically broadcasts its identification code through the down link control channel (for example, DCCH in GSM systems). The goal of the CIC is to provide the location information required to the users, in order to perform the registration strategy.

The first issue addressed in this paper is the proposal of efficient cell identification encoding schemes, each geared towards a different tracking strategy. We propose three CIC encoding schemes. The first, achieving the best performance, is the proposition of a CIC for implementing a distance-based tracking strategy. We show that for a realistic two dimensional topology a four bit message is sufficient to provide a reliable distance-based tracking. We analyze the conditions under which the proposed CIC is guaranteed to properly function. Secondly, we propose a combined timer and movement tracking strategy, based on either a one-bit or a two-bit CIC, depending on system topology and user mobility. We show that the movement-based tracking strategy is a special case of the combined timer and movement tracking strategy. The third proposition is a conditional timer strategy, in which the user examines its current location every T time units, using a CIC, and if it differs from its last known location – it transmits a registration message.