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LeZi-Update: An Information-Theoretic Framework for Personal Mobility Tracking in PCS Networks

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Abstract. The complexity of the mobility tracking problem in a cellular environment has been characterized under an information-theoretic framework. Shannon's entropy measure is identified as a basis for comparing user mobility models. By building and maintaining a dictionary of individual user's *path* updates (as opposed to the widely used location updates), the proposed adaptive on-line algorithm can learn subscribers' profiles. This technique evolves out of the concepts of lossless compression. The compressibility of the variable-to-fixed length encoding of the acclaimed Lempel–Ziv family of algorithms reduces the update cost, whereas their built-in predictive power can be effectively used to reduce paging cost.

Keywords: location management, update, paging, mobility model, entropy, LZ78 compression

1. Introduction

Seamless and ubiquitous connectivity is the strongest driving force today in designing a Personal Communication Service (PCS) network environment. The need to track down a mobile user for satisfying these connectivity requirements leads to what is commonly known as the *mobility tracking* or *location management* problem. In short, while enjoying the freedom of being mobile, the user creates an *uncertainty* about the exact location of the registered portable device or *mobile terminal* (henceforth called just *mobile)* being carried. The collector network deployed by the service provider has to work against this uncertainty for a successful call delivery. Furthermore, this has to be done effectively and efficiently for every PCS subscriber. To avoid dropping, a call must be routed to the recipient within an allowable time constraint, yet with as little information exchange as possible. Transfer of any more message than necessary results in wastage of valuable resources such as scarce wireless bandwidth and mobile equipment power, thus increasing the operational cost that the user has to bear ultimately.

The wireless network for a PCS system is still built upon an underlying *cellular* architecture. The service area is divided into a collection of *cells,* each serviced by a *base station* (BS). Several BSs are usually wired to a *base station controller* (BSC), and a number of BSCs are further connected to a *mobile switching center* (MSC) forming a tree-like cluster. This hierarchical wired connection of the MSC, BSCs and BSs, along with the air-link between the BSs and the mobiles form the *collector network.* The *backbone* of the PCS network consists of the existing wire-line networks (such as PSTN, ISDN and the Internet) interconnecting the collector networks. The MSCs act as the gateway for the collector network to the backbone.

As a whole, location management involves two kinds of activities – one on the part of the system and the other on the part of the mobile. On a call arrival, the system initiates a search for the target mobile, by simultaneously polling all the cells where it can possibly be found. The MSC broadcasts a *page* message over a designated *forward control channel* via the BSs in a set of cells where the mobile is likely to be present. All the mobiles listen to the page message and only the target sends a response message back over a *reverse channel.* This search mechanism is called *paging.* In case no information about the mobile is available, the system may have to page all the cells in the service area. As the PCS providers are shooting for larger and larger (even continent-wide) service areas, the paging-only location tracking turns out to be inadequate. If an exhaustive search is performed for each and every call that arrives, the signaling traffic would become enormous even for moderately large networks [23]. The limited number of paging channels are bound to overload as the call volume grows. To put an upper bound on the amount of *location uncertainty,* a mobile is made to report from time to time. This reporting, called *location update* or *registration,* effectively limits the search space for paging at a later point of time. The registration mechanism starts with an *update message* sent by the mobile over a *reverse channel,* which is followed by some traffic that takes care of related database maintenance operations.

In this paper, we take a novel approach to tackling the location management problem, and characterize its complexity from an *information-theoretic* viewpoint. This outlook provides the insight to design an adaptive on-line algorithm for tracking a mobile, which is *optimal* in terms of both update and paging costs. The objective of our update scheme is to *learn* user mobility with optimal message exchange. Learning endows the paging mechanism with a predictive power which reduces average paging cost. A preliminary version of this paper appeared in [6].

In section 2, we provide a taxonomical classification of the existing location management techniques. Section 3 explains