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A Bio-Inspired Approach for the Next Generation of Cellular Systems

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INTRODUCTION

In the current 3G systems and the upcoming 4G wireless systems, *missing neighbor pilot* refers to the condition of receiving a high-level pilot signal from a Base Station (BS) that is not listed in the mobile receiver's neighbor list (LCC International, 2004; Agilent Technologies, 2005). This pilot signal interferes with the existing ongoing call, causing the call to be possibly dropped and increasing the handoff call dropping probability. Figure 1 describes the missing pilot scenario where BS1 provides the highest pilot signal compared to BS1 and BS2's signals. Unfortunately, this pilot is not listed in the mobile user's active list.

The horizontal and vertical handoff algorithms are based on continuous measurements made by the user equipment (UE) on the Primary Scrambling Code of the Common Pilot Channel (CPICH). In *3G systems,* UE attempts to measure the quality of all received CPICH pilots using the Ec/Io and picks a dominant one from a cellular system (Chiung & Wu, 2001; El-Said, Kumar, & Elmaghraby, 2003). The UE interacts with any of the available radio access networks based on its memorization to the neighboring BSs. As the UE moves throughout the network, the serving BS must constantly update it with neighbor lists, which tell the UE which CPICH pilots it should be measuring for handoff purposes. In *4G systems*, CPICH pilots would be generated from any wireless system including the 3G systems (Bhashyam, Sayeed, & Aazhang, 2000). Due to the complex heterogeneity of the 4G radio access network environment, the UE is expected to suffer from various carrier interoperability problems. Among these problems, the missing neighbor pilot is considered to be the most dangerous one that faces the 4G industry.

The wireless industry responded to this problem by using an inefficient traditional solution relying on using antenna downtilt such as given in Figure 2. This solution requires shifting the antenna's radiation pattern using a mechanical adjustment, which is very expensive for the cellular carrier. In addition, this solution is permanent and is not adaptive to the cellular network status (Agilent Technologies, 2005; Metawave, 2005).

Therefore, a self-managing solution approach is necessary to solve this critical problem. Whisnant, Kalbarczyk, and Iyer (2003) introduced a system model for dynamically reconfiguring application software. Their model relies on considering the application's static structure and run-time behaviors to construct a workable version of reconfiguration software application. Self-managing applications are hard to test and validate because they increase systems complexity (Clancy, 2002). The ability to reconfigure a software application requires the ability to deploy a dynamically hardware infrastructure in systems in general and in cellular systems in particular (Jann, Browning, & Burugula, 2003).

Figure 1. Missing pilot scenario

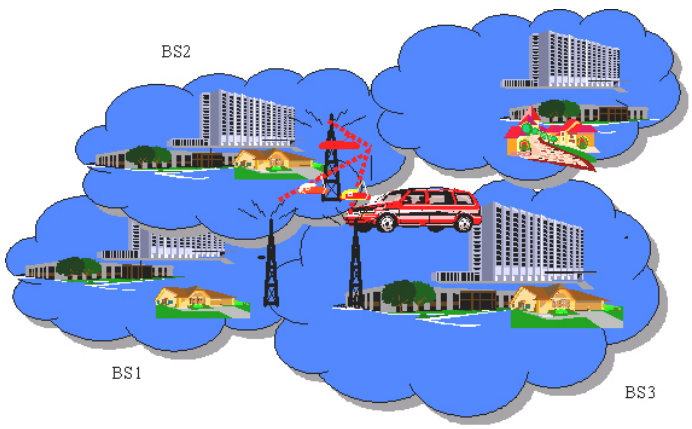
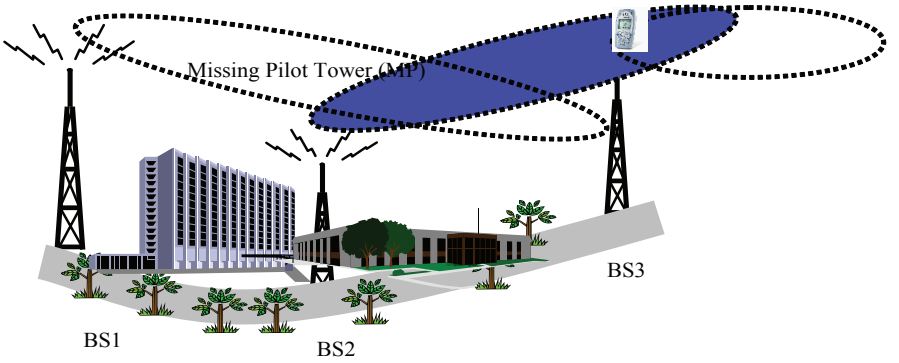


Figure 2. Missing pilot solution: Antenna downtilt



Konstantinou, Florissi, and Yemini (2002) presented an architecture called NESTOR to replace the current network management systems with another automated and software-controlled approach. The proposed system is inherently a rule-based management system that controls change propagation across model objects. Vincent and May (2005) presented a decentralized service discovery approach in mobile ad hoc networks. The proposed mechanism relies on distributing information about available services to the network neighborhood nodes using the analogy of an electrostatic field. Service requests are issued by any neighbor node and routed to the neighbor with the highest potential.

The autonomic computing system is a concept focused on adaptation to different situations caused by multiple systems or devices. The IBM Corporation recently initiated a public trail of its Autonomic Toolkit, which consists of multiple tools that can be used to create the framework of an autonomic management system. In this article, an autonomic engine system setting at the cellular base station nodes is developed to detect the missing neighbor (Ganek & Corbi, 2003; Haas, Droz, & Stiller, 2003; Melcher & Mitchell, 2004). The autonomic engine receives continuous feedback and performs adjustments to the cell system's neighboring set by requiring the UE to provide signal measurements to the serving BS tower (Long, 2001).

In this article, I decided to use this toolkit to build an autonomic rule-based solution to detect the existence of any missing pilot. The major advantage of using the IBM autonomic toolkit is providing a common system infrastructure for processing and classifying the RF data from multiple sources regardless of its original sources. This is a significant step towards creating a transparent autonomic high-speed physical layer in 4G systems.

PROPOSED SOLUTION

The proposed AMS relies on designing an autonomic high-speed physical layer in the smart UE and the BS node. *At the UE side,* continuous CPICH pilot measurements will be recorded and forwarded to the serving BS node via its radio interface. *At the BS node,* a scalable self-managing autonomic engine is developed using IBM's autonomic computing toolkit to facilitate the mobile handset's vertical/horizontal handover such as shown in Figure 3. The proposed engine is cable of interfacing the UE handset with different wireless technologies and detects the missing pilot if it is existed.

The autonomic engine relies on a generic log adapter (GLA), which is used to handle any raw measurements log file data and covert it into a standard format that can be understood by the autonomic manager. Without GLA, separate log adapters would have be coded for any system that the autonomic manager interfaced with. The BS node will then lump all of the raw data logs together and forward them to the Generic Log Adapter for data classification and restructuring to the common base event format. Once the GLA has parsed a record in real time to common base event format, the autonomic manager will see the record and process it and take any action necessary by notifying the BS node to make adjustments to avoid the missing pilot and enhance the UE devices' quality of service.

PERFORMANCE MEASUREMENTS AND KEY FINDINGS

To test the applicability of the proposed solution, we decided to use the system's response time, AS's service rate for callers experiencing missing pilot problem, and the performance