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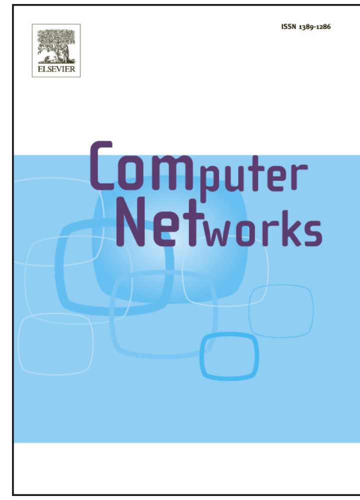

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Abstract

This paper presents a novel approach for self-healing in cellular networks based on the application of mobile terminals context information: time, service, activity, identity and, especially, location. Context information is therefore used to support root cause analysis, providing improved network fault diagnosis compared to classical non-context-aware approaches. The integration of context information is implemented by means of the newly defined contextualized indicators. These are used in order to integrate user equipment context information in pre-existent failure management schemes. The presented techniques are especially suitable for indoor small cell scenarios, whose particular conditions of dynamic user distribution, overlapping coverage, dynamic radio and service provisioning environment, etc., make previous diagnosis schemes especially unreliable. The algorithms and methodology for the proposed context-aware system are defined and its performance is assessed by means of an LTE system-level simulator.

Keywords: Self-healing; diagnosis; context-aware; localization; small cells; LTE.

1. Introduction

Troubleshooting is one of the most time and resource-consuming tasks in cellular network operations. Faults in network elements (e.g. in base stations, backhaul, etc.) often end up requiring field engineers and/or technicians visits to the site, which introduce high expenditures. Base stations are extremely complex systems, composed of multiple and redundant equipment, from the power supply to the pure communication subsystems. The lack of a proper knowledge of the causes of a failure can easily lead to high delays in fault recovery. This may include multiple visits to the site and/or long system monitoring time, with the corresponding costs and disruption of the user service, which strongly impacts the operator brand image.

Operators and standardization bodies have proposed different approaches to reduce these expenditures by means of automating network failure management. In this field, the Next Generation Mobile Networks (NGMN) Alliance [1] and the 3rd Generation Partnership Project (3GPP) [2] defined the Self-Organizing Networks (SON) concept [3]. SON encompasses three main areas of cellular system operations, administration and management (OAM): self-configuration, the initial automatic configuration of the network elements; self-optimization, the tuning of network parameters to adapt the system to changes; and self-healing, the automatic identification and correction of network failures.

Self-healing consists of fault detection, root cause analysis (diagnosis), compensation and recovery. In spite of being one of the key factors to keep the quality of service (QoS), self-healing has been scarcely analyzed in the literature, partly due to the intrinsic difficulties of network failure identification in such a complex system as a cellular network.

On the one hand, new challenges greatly impact the application of self-healing in current deployments. Cellular infrastructure consists in heterogeneous networks (HetNets). These are characterized by the simultaneous coexistence and interaction of multiple radio access technologies (RATs) such as GSM, UMTS, LTE (Long-Term Evolution) and different cell station deployment models (e.g. femtocells, picocells, etc.). HetNets complexity leads to an increased demand for automatic, fast and accurate diagnosis mechanisms.

On the other hand, the wide market penetration of smartphones and tablets (about the 74% of mobile terminals [4]) enlarges the amount of distributed sensing and computational capacity in the network. New mobile terminals are powerful platforms highly equipped with sensors and applications that increase the availability of terminals and users' *context information* [5]. Context encompasses information on the user conditions such us location, activity, etc., opening the opportunity to make use of this data for network diagnosis purposes.

In this way, *user equipment* (UE) data can be included as a new source of information for self-healing, where such solutions are especially promising in the field of indoor deployments of small cells. Small cells are low powered base stations aiming to provide specific coverage to certain spots and increasing frequency reuse [6]. Their de-

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