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Towards connecting people, locations and real-world events in a cellular network

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ABSTRACT

The success of personal mobile communication technologies has led an emerging expansion of the telecommunication infrastructure but also to an explosion to mobile broadband data traffic as more and more people completely rely on their mobile devices, either for work or entertainment. The continuously interaction of their mobile devices with the mobile network infrastructure creates digital traces that can be easily logged by the network operators. These digital traces can be further used, apart from billing and resource management, for large-scale population monitoring using mobile traffic analysis. They could be integrated into intelligent systems that could help at detecting exceptional events such as riots, protests or even at disaster preventions with minimal costs and improve people safety and security, or even save lives. In this paper we study the use of fully anonymized and highly aggregate cellular network data, like Call Detail Records (CDRs) to analyze the telecommunication traffic and connect people, locations and events. The results show that by analyzing the CDR data exceptional spatio-temporal patterns of mobile data can be correlated to real-world events. For example, high user network activity was mapped to religious festivals, such as Ramadan, Le Grand Magal de Touba and the Tivaouane Maouloud festival. During the Ramadan period it was noticed that the communication pattern doubled during the night with a slow start during the morning and along the day. Furthermore, a peak increase in the number of voice calls and voice calls duration in the area of Kafoutine was mapped to the Casamance Conflict in the area which resulted in four deaths. Thus, these observations could be further used to develop an intelligent system that detects exceptional events in real-time from CDRs data monitoring. Such system could be used in intelligent transportation management, urban planning, emergency situations, network resource allocation and performance optimization, etc.

1. Introduction

The outstanding progress of the telecommunication industry and the smart mobile computing devices, led to a significant growth in the number of advanced mobile users and their service demands. Users now are expecting uninterrupted, continuous and seamless services that satisfy the Quality of Service (QoS) demands of their applications when connecting to the

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Internet from any device type and at anytime, either while on the move or stationary. According to Cisco (2015), 66% of the IP traffic is generated from mobile and wireless devices and the Internet traffic will reach 18 GB per capita by 2019. To be able to deal with this explosion of mobile broadband data traffic and satisfy their customers' traffic demands, the network operators started exploring the next generation of wireless infrastructure, which includes a high deployment of base stations and overlapping of different radio access technologies (RAT), such as Wireless Local Area Networks (WLAN), Long Term Evolution (LTE), Worldwide Interoperability for Microwave Access (WiMAX), etc. This heterogeneous wireless environment will provide the mobile users with high performance and wide coverage motivating the continuing uptake of the mobility around the world.

By continuously interacting with the mobile network infrastructure a digital signature can be easily recorded from each mobile computing device by the network operators. Thus, every time people interact with the mobile networks or any type of social media platform, they leave behind digital traces that network operators could use for different purposes, such as: billing or network resource management. This data collected from the mobile systems is referred to as Call Details Records (CDRs), which contain information details about every call carried within the cellular network, including information about the location, call duration, call time, and both parties involved in the conversation. The CDR traces have become a powerful tool to analyze human behavior patterns and an increased interest towards making use of CDRs to analyze the human mobility cheaply, frequently and especially at a very large scale has been recorder lately. Various studies have shown that several areas could benefit from understanding human mobility patterns, such as: network resource optimization, mobile computing, transportation systems, urban environment planning, events management, epidemiology, etc.

Within this context, our research questions are: can the CDR data be used to detect exceptional spatio-temporal patterns of the collective human mobile data usage? Can we correlate these exceptional usage patterns to real-world events?

In this work we provide a comprehensive literature review and we explore the use of anonymized CDRs containing data from voice-calls and SMS activities, collected over one year period from more than nine million mobile customers within a cellular network in Senegal. The data is analyzed and the results show that exceptional spatio-temporal patterns of the collective human activity could be identified from fully anonymized and highly aggregate cellular network data, like CDRs, and correlated with real-world events, such as religious festivals (e.g., Ramadan, Le Grand Magal de Touba and the Tivaouane Maouloud festival) and even conflicts (e.g., Casamance Conflict that resulted in four deaths). Apart from analyzing the correlation of the exceptional spatio-temporal patterns with real-world events, the study also analyses the telecommunication traffic flows. The observations from this study could be further used to develop an *intelligent system that detects exceptional events in real-time* from CDRs monitoring. The benefits of such systems could be threefold: (1) the *network operators* could benefit by detecting congested cells and optimize their network resources in advance of an exceptional event, e.g., make use of the Wi-Fi offloading solutions, enabling adaptive bandwidth allocation to their radio cells, etc.; (2) *the society* could benefit from intelligent transportation and urban planning and management; (3) *the individual* could benefit from traffic information and prediction, emergency management. For example, a real-time event detection system could be used in case of emergency situations, such as conflicts or riots protests which could be more efficiently handled if detected and handled on time.

2. Related works

The use of user-generated traffic from mobile communications networks as a powerful tool to analyze human behavior, as well as mobile traffic analysis have become an extensive academic research area which is rapidly emerging over a wide range of disciplines. Moreover, considering the fact that billions of people around the world own at least one mobile device, the digital traces collected from the mobile communications networks could help study different aspects of human mobility and their interactions on a large scale. A comprehensive survey on the use of large-scale mobile traffic analysis in multidisciplinary activities is provided by Naboulsi et al. (2016). Saramäki and Moro (2015) look into the use of mobile phone traffic datasets for extracting social graphs. Another extensive review on analysis of mobile phone datasets is provided by Blondel et al. (2015). This section provides a survey on user-generated traffic from mobile communications networks used to understand different aspects of human movement and their interaction. The existing solutions are divided into three main categories: (1) universal law for human mobility; (2) urban planning and traffic forecast; and (3) localization and mobility patterns.

2.1. Universal law for human mobil ity

Several works tried to define some basic laws governing the human motion from CDR data in order to understand the human mobility patterns. In this regard, González et al. (2008) tracked the position of 100,000 anonymized mobile phone users over a six month period and showed that individuals follow simple reproducible patterns despite the diversity of their travel history. As the users always return to several of their highly frequented locations such as home or work, significant regularity can be identified in their trajectories. Empirical data on human mobility was also used by Song et al. (2010a) to show that the predictions provided by the continuous time random walk (CTRW) models