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A measurement study of short-time cell outages in mobile cellular networks

Josip Lorincz[a], Luca Chiaraviglio[b,*], Francesca Cuomo[b]

[a] FESB, University of Split, Split, Croatia
[b] DIET Department, University of Rome Sapienza, Rome, Italy

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ABSTRACT

We study the Short-Time Cell Outages (STCO) phenomena affecting Base Stations (BSs) in a mobile cellular operator network. The STCO is defined as a short-time outage of all or some BS cells (sectors) that lasts up to 30 min in a day, thus still guaranteeing more than 98% of operation. It is type of outage which cannot be detected directly through an operator network monitoring system. Although a complete characterization of STCOs has never been reported in the literature, such events are affecting the cellular network of every mobile operator. In particular, a statistical analysis of STCOs based on BSs measurements of a complete operator mobile network is performed. Our results show that: (i) STCOs impact everyday life of an operator network, (ii) high load of cells corresponds to an increase in the number of STCOs and their duration, (iii) the impact of STCOs to single sectors and whole BSs is not negligible, (iv) most of STCOs are recorded in urban areas compared to rural ones, (v) the impact of STCOs on users is higher in rural areas compared to urban ones, and (vi) the STCOs are correlated with the transferred traffic rather than the outside air temperature.

1. Introduction

Equipment outages in cellular access networks result in degradation or complete service interruption. Such occurrences cause operator revenue losses and users dissatisfaction [1]. After price and network coverage, outages are now considered the third most significant factor influencing subscribers churn [2], what additionally contributes to the revenue losses. Mostly, mobile operator technical staff detects outages in real time, through reception of automated failure logs sent to the Operations and Maintenance Center (OMC) [3].

In this paper, characteristics of special types of outage named Short-Time Cell Outages (STCOs) are analyzed. They can be perceived by the operator as hidden outages, since most of them cannot be directly detected through failure logs received by the OMC. Instead, awareness of those outages can be gained indirectly, through subscriber complaints, service traffic decrease or by extracting data from an operator Performance Monitoring (PM) system such as Ericsson Network IQ (ENIQ) solution [4].

In order to be classified as STCO, allocated Transmit Channel(s) (TCHs) of all or some Base Station (BS) cells (sectors) must be in an outage state for up to 30 min in a single day. In the coverage area of a cell, users experience a lack of service during outage period(s). Such 30 min downtime takes into account single outage lasting up to 30 min, or a sequence of shorter outages (more than one) with total duration equal or less than 30 min in a day.

Although cell outages lasting more than 30 min in a day (classified in the paper as Long-Time Cell Outages - LTCOs) also exist in cellular networks, there are several important reasons which motivate the analysis of STCOs. Firstly, some previous research works have already reported characterization of failures and outages in cellular networks [5] and Internet protocol (IP) backbone networks [6]. However, that characterization was dedicated to all outage types lacking conclusions related to the frequently occurred STCOs. Secondly, although most of the mobile operators are aware of the STCOs, up to 30 min outage in a day still ensures fully BS cell operation for minimally 98% time of a day. Hence, the BSs having STCO(s) are fully operational between 98% and 99.999% of a day, that is from the operator's perspective acceptable daily operation time. Thirdly, operators treat elimination of LTCOs with stronger attention, with the goal of as fast as possible outage elimination. However, analyses of failure and recovery rates in [5,7] report that high percentage of failures in cellular access networks are self or auto recovered. Hence, many STCOs are caused

* Corresponding author. Tel.: +39 3475032520,+39 644585467; fax: +39 64744481.
E-mail addresses: jlerinc@fesb.hr (J. Lorincz), luca.chiaraviglio@uniroma1.it, luca.chiaraviglio@gmail.com (L. Chiaraviglio), francesca.cuomo@uniroma1.it (F. Cuomo).

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by self/auto-recoverable failures lacking any manual intervention for the outage recovery. This fact additionally alienates operator attention from such type of outages. Fourthly, the importance of cell outages has been recognized by the 3rd Generation Partnership Project (3GPP). The 3GPP ongoing work in developing Technical Specification (TS) 32.541 (Release 12), addresses mitigation of cell outages through automated self-healing process which is part of the next generation Self-Organizing Network (SON) concept [6,8]. Hence, the analysis presented in this paper can be useful for future development of cell outage detection and compensation algorithms which are currently topic of great interest [9–11].

All these facts, combined with limited access to the cell outages data obtained from real cellular networks, are the rationale of statistical analyses of the BSs STCOs like the one proposed in this paper. Causes of such outages are similar to those of LTCOs. They are related with BSs software/hardware failures, congestion (load), temperature variations, power supply outages, environment causes (e.g. storm and/or lighting), etc. Such outages are inherent for operators BSs of the second (2G), third (3G) and forth (4G) generation. Also, analyses show that most of operators see space for improvement in understanding the causes of their outages [2]. Hence, in depth understanding of STCOs characteristics can help operator technical staff, researchers and equipment manufacturers to minimize or even eliminate the outages causes during network planning and operation phase.

According to our knowledge, this is the first paper which analyses the STCOs behavior in real cellular networks. The main contributions of this paper are: (i) explanation of weekly temporal variations of the STCO pattern in terms of number and duration of the STCOs per BS and cell, (ii) deep analysis of spatial variations of the STCOs based on Cumulative Distributing Function (CDF) of number and duration of the STCOs per BS and cell, (iii) estimation of not transferred traffic caused by STCOs on the level of complete operator network, (iv) indication of interdependence among Mean Time Between Outages (MTBO) and duration of STCOs, (v) presentation of differences among STCO statistics for BSs and cells covering urban and rural areas, and (vi) investigation of possible causes of STCOs.

The rest of the paper is organized as follows. Section 2 overviews the related work. Section 3 details how to detect and extract the STCOs from real measurements of a cellular network. Results from a measurement campaign of a national operator network are reported in Section 4. Section 5 discusses how mobile networks could be improved in order to limit the impact of STCOs. Finally, Section 6 concludes the paper.

2. Related work

Equipment outages impact the performance of telecommunication networks. Authors of [6] have performed a detailed characterization of outages in an operator backbone network, by leveraging on the Intermediate System to Intermediate System (IS–IS) routing updates to detect the failure events. The Authors perform also a preliminary investigation of possible causes of failures in the network, showing that maintenance operations, router-related and optical-related problems are the main causes of failure events. Moreover, the spatial and temporal variations of traffic are considered (e.g., showing that the outages follow a Weibull distribution). Differently to them, in this work we have considered a different scope, i.e., a cellular network rather than a transport backbone network. Similarly to them, however, temporal and spatial behaviors emerge also in our case, suggesting that common characteristics can be inferred (e.g., the mean time between STCOs follow a Weibull distribution like in [6]).

In [5] the Authors investigate the impact of failures and changes in the network (e.g., deploying new BSs, or changing the old ones).

Table 1
Data set features.

Feature	Value
Total number of subscribers	≈0.5 millions
BS location	nation-wide
Total number of BSs	≈800
Total number of sectors	≈2400
Overall measurement time	7 days
Time granularity	15 min
Total number of outage events	3560
Maximum daily STCO duration	30 min

However, the impact of STCOs is not considered, e.g. only classical outages are analyzed. Differently from them, our work is tailored to the investigation of STCOs, showing that their impact is far to be negligible. Additionally, we consider the impact of traffic and the role of the sectorization on the intensity of such failures.

Additionally, in [7] the Authors provide estimates of the mean time between failures and the mean time to repair in a cellular scenario, showing that both of them follow a Weibull distribution (and not an exponential one). Moreover, they claim that most of software failures are auto-recovered in practice. Our work, even if tailored to STCOs and not to classical failures like [7], confirms these findings. Although the fitted distributions are the same of [7], their parameters are quite different, due to the fact that STCOs have been not considered in that previous work.

Finally, in [12] the Authors analyze the number of calls, SMS, and data transfers considering both spatial and temporal variations for different cities. The analysis reveals that there is a strong day night-trend in the analyzed features. Additionally, spatial differences emerge from the proposed data (especially when business or residential districts are analyzed). Our work also considers the temporal variations of the cellular features. However, differently from [12] we focus our attention on the analysis of STCO failure events vs. time, which should be an additional metric that should be taken into account by an operator.

3. How to detect and extract the STCOs

The main characteristics of the STCOs phenomena affecting BSs of an operator mobile access networks is that STCOs are hard to detect and to follow in real time, due to the frequent STCO appearance, its short duration and auto-recovery behavior. Actually, STCOs are recovered faster than mobile operator becomes aware about details of each STCO occurrence. For example, short BS power supply variation, preventive BS activity state transition due to excessive temperature increase or decrease inside BS rack, autorecovery software or hardware failures and temporal cell interference or congestion are some of the main causes of STCOs. For that reason, STCOs are not detected directly through reception of automated failure logs sent to the OMC of an operator. Instead, outages are detected indirectly from operator performance monitoring system.

Analyses of the STCOs have been performed on data measured in the whole access network of a national operator, having approximately 800 BS sites equipped with 2G and 3G technologies. Those BS sites offer overall cellular coverage on the national level. In the analyses, only 2G BSs are taken into account. Reasons can be found in the cellular network configuration, which is set up in a way that the 2G technology dominantly accepts voice, while the 3G one dominantly accepts data traffic. Since the voice traffic is intolerant to any kind of cell outages, it is assumed that analyzing STCOs of the 2G technology can offer highest contribution in terms of obtained results. Table 1 summarizes the main features of the considered data set. In order to guarantee operator