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Improved Network Analytics with novel feedback quantities for Self-Optimized Networks

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Abstract

With the ever-increasing Capital Expenditure (CAPEX) required for newer technologies like New Radio (NR) to meet 5th Generation (5G) requirements, it is imperative for the operators to look at reduced Operation and Maintenance (O&M), as a way to optimize the Return on Investment (RoI) over several years. Self-Optimizing Networks (SON) are emerging as the key component for cellular operators, and it is a big game changer for reduction in O&M of the operators by automatically enhancing network performance, coverage and capacity. In this paper, we propose schemes to add new dimensions to SON by incorporating novel measurement quantities in the of Minimization of Drive Test (MDT) logging feedback, which serve to enhance the functionality of Network Analytics. The incorporation of the measurements for 'battery drain rate', 'mobility state' and 'out of coverage cause' in the feedback can deliver substantial gain over existing feedback parameters.

Keywords: SON, Network Analytics, MDT, UE Feedback.

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1. Introduction

The sheer complexity and size of the current wireless cellular networks places mammoth demands on the operators in terms of the operational expenses required for their maintenance. It has been envisaged that going forward, cellular networks should have the capability to self-organize and self-optimize the networks in order to heavily curtail the operational and maintenance (O&M) expenses by minimizing human intervention. The User Equipment (UE) can provide a large number of measurement quantities which the Network Analytics function in the Self Organizing Networks (SON) paradigm can use to fine tune, enhance and optimize the network, as depicted in Fig 1. This inherently reduces the need for human intervention such as for drive tests as the existing UEs can report the intended measurements.

SON refers to the functionality of self-configuration, self-optimization and self-maintenance in order to enhance network performance, coverage and capacity [1]. Self-configuration process is defined as the process where newly deployed Base Stations (BS) can be automatically configured for the essential basic configuration required for system operation. This procedure typically includes operations like establishing links with other network nodes (e.g., Gateway), generating neighbour relation list of the surrounding BSs. Self-Optimization refers to the process where UE and BS measurements are used to auto tune the network parameters resulting in coverage and capacity optimization besides enhancing network performance. Self-maintenance refers to the process of auto healing which involves automatic detection and repair of most of the network failures. These aspects of SON can either be localized or distributed in functionality [1]. Upcoming cellular standard bodies like 3GPP are actively considering SON as it is imperative to bring down the O&M costs and SON provides an elaborate framework in order to achieve this objective [3][5][6][7].

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In this paper we deal with the Network Analytics aspects which are directly related to air interface. Typically the measurements required for SON to function can be categorized as UE assisted and UE non-assisted. In this paper we further delve in the UE assisted measurements for SON and add novel parameters/UE measurements which can help SON to enhance the network coverage and capacity optimizations. In Section II, we have captured the UE feedback parameters as being standardized by 3GPP in the Minimization of Drive Test (MDT) Work Item (WI). Section III proposes the new feedback quantities and the benefits it can accrue to SON.

2. UE Feedback

Feedback from UE can assist in optimizations over the air interface [3]. The feedback can be on radio coverage information with location information, information about performance of radio functionalities that are executed autonomously by the UE, information about failures that are not known to the network, additional information on failures that are known to the network, information about network performance within specific geographic areas, information about performance along inter-RAT (Radio Access Technologies) boundaries and information about faults in network and UE implementation. In order for the feedbacks to be reported, the UE should be able to communicate its capability to an O&M network entity (e.g. SON server), including UE measurement capability (e.g. GPS, time stamp), UE logging capability (e.g. number of logs, supported log triggers) and UE reporting capability (e.g. frequency of reporting) This in turn enables the SON server to configure the appropriate measurements, and reporting policy at the UE [3] [4]. The UE should be able to log measurements configured by the O&M network entity. It should be possible that the O&M network entity configure the scope of UE measurement logging (e.g. PLMN, Tracking Area, cell(s)). The UE should be able to report logs based on the reporting policy configured by the O&M network entity. No real time reporting is expected upon UE logging as it is done if the existing event triggered reporting. The scheme is captured in Fig. 2.
In general UE feedback should assist in the use cases for SON viz. Coverage and Capacity optimization, Mobility robustness optimization, Interference reduction, Random Access Channel (RACH) optimization, Load balancing, Energy savings and Parameterization of common channels [2]. These use cases of SON are further illustrated below.

2.2. Coverage and Capacity Optimization

Information about radio coverage is essential for network planning, network optimization and Radio Resource Management (RRM) parameter optimization (e.g. idle mode mobility parameter setting), as well as backend network management activities, such as network dimensioning, CAPEX/OPEX planning and marketing [2]. Additionally the detection of coverage problems (e.g. coverage holes, pilot pollution) in specific areas is performed, e.g. based on customers complaints, along roads or train lines, in case of special events. UE can provide a measurement log with information of coverage loss (no suitable cell present), recorded with timestamp, last camped cell and GPS position. The UE can be configured with measurement triggers which can be periodical (timer based), or event based like when the serving cell becomes worse than a threshold, RRC connection re-establishment, and/or random access failures.

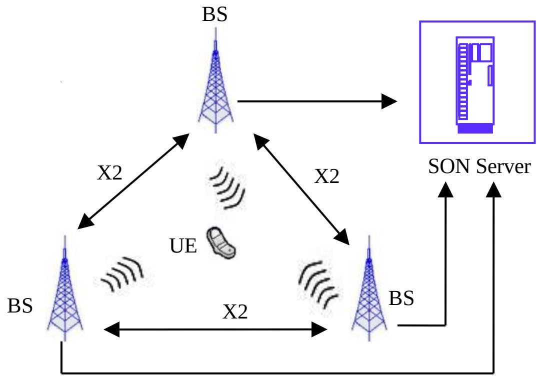

Figure. 1. Network Analytics by UE assisted measurements in E-UTRAN

2.3. Mobility robustness optimization

Mobility is characterized by service disruption (e.g. data interruption, missed paging). Mobility parameters are chosen to avoid unexpected radio link loss events or unnecessary mobility events (e.g. ping-pong, too early or too late handovers) [2]. UE can provide a measurement log with details on ping pong reselections recorded with involved cells, time and position can be handy. The UE can be configured with measurement triggers which can be event based like RRC connection re-establishment and/or Location Area (LA) or Routing Area (RA) or Tracking Area (TA) update failures.

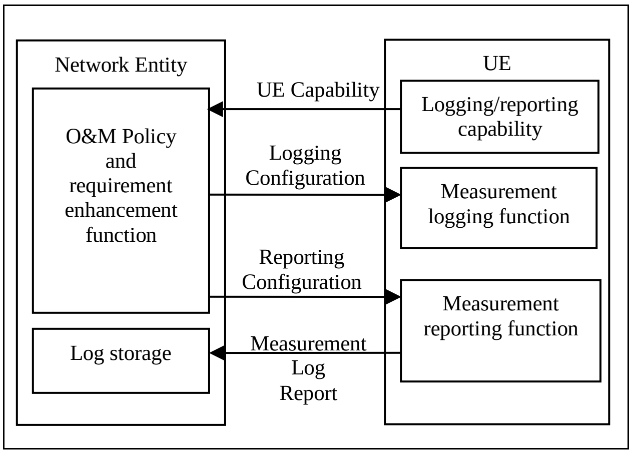

Figure 2. UE Feedback scheme

TABLE 1. IDLE MODE - BATTERY DRAIN REPORT

Battery Drain Rate	Applicable SON Configuration
High	• Remove Neighbor cells in System Information, • Topology change for Detected Cells, • Adjust thresholds for measurements • Adjust TAU timer, • Adjust RACH TX /Re-TX parameters
Medium	- do-
Low	• Add neighbor cells (if required)

3. Novel UE measurement and feedback quantities

3.1. Idle/Connected mode battery drain rate

Idle time is a measure of available battery backup when the phone is not in conversation mode where it only maintains connectivity to the network, and receives paging for all incoming calls and messages. In a typical non-connected mode, UE needs to perform basic operations like:

- Neighbour/Detected cell measurements (for candidate intra-frequency cells)
- Neighbour/Detected cell measurements (for candidate inter-frequency cells)
- Neighbour/Detected cell measurements (for candidate inter-RAT cells)
- Read System information (mandatory SIBs) when criteria of reselection is met
- Perform TAU (Location Update/RAU) when the reselected cell is in new TA/LA/RA
- In addition decode Paging Blocks at appropriate Paging occasions.

TABLE 2. CONNECTED MODE - BATTERY DRAIN REPORT

Battery Drain Rate	Applicable SON Configuration
High	• Remove Neighbor cells in Measurement Control (RRM), • Topology change for Detected Cells, • Adjust thresholds for measurements • Adjust RLF timer, • Adjust Connected Mode DRX • Adjust Gap Patterns
Medium	- do-
Low	• Add neighbor cells (if required)

Thus, a lot of factors for the perceived idle time at the UE are dependent on the network configuration (Common Channel Parameters). It is possible that a UE which expects an idle time of 4 days in a cell, will experience 2-3 days on another cell, because of possible differences in DRX length, number of neighbour cells/detected cells and/or Random access parameters. Thus a report of the perceived idle time, can give the network a fair idea of what parameters would need to be changed/configured for the perceived idle time for the UE to increase. Network needs to define thresholds for quantizing, using which UE should quantize the perceived rate of battery drain in idle mode as "high", "medium", and "low". The UE can be configured with measurement triggers which can be periodical (timer based). This report can be applied by the SON Server in optimizing the network topology as illustrated in Table 1.
The target should be to keep the idle state’s battery drain rate between low and medium, without affecting the performance.
A similar measurement of the "talk time" perceived by the UE can give a fair idea to the possible change in configuration of the network for the mobility parameters, which control handovers, and/or dedicated bearer parameters used in Physical channel configuration. The same can be derived from the rate at which the battery is drained in the UE. UE should also quantize the perceived rate of battery drain in connected mode as "high", "medium", and "low". The UE can be configured with measurement triggers which can be periodical (timer based). The SON Server in optimizing the connected mode topology/configuration as illustrated in Table 2 can apply this report.
The UE can optionally report other parameters (common channel and dedicated channel parameters) for a previous "high" measurement on some other cell, TA, or Public Land Mobile Network (PLMN), for the network to compare/configure the parameters of the current cell/TA/PLMN with those of the other cell (in case the two network entities are not directly connected). Additionally, it can get the parameters through X2-interface/backhaul.

The proposed measurements will help in network planning, and idle/dedicated mode configuration, neighbor cell planning, and cell planning in general. This will also help mobile phone vendors in increasing the idle and talk time perceived by the user, thereby delivering a good user experience in a given network.
The above proposal can help in the following use cases as required for SON [2].

- Coverage optimization: The network can semi-statically configure the RRM. Too many or too few reselections can be controlled. A high battery drain rate can also be an indication of a badly planned topology of cells which is leading to a ping-pong effect.

TABLE 3. MOBILITY STATE - REPORT

Speed Threshold	SON Configuration/Application
Low	• Adjust thresholds for speed measurement filter (N_{CR_M}, N_{CR_H} and T_{CRmax}) • Adjust scaling factor for idle and connect mode (reselection and handover) • Adjust Gap Patterns based on speed
Medium	- do-
High	-do-

3.2. Mobility State of UE

UE can also report the mobility state to the network. The mobility state is continuously being updated by the UE as "high", "medium" or "low" [5].
UE can also be supporting measurement of absolute speed/velocity (by means of GPS/other sensors). There can be thresholds defined by the network , thus the UE capable of measuring their absolute speed can measure the number or reselections (intra-frequency, inter-frequency and inter-RAT) done when traveling above a threshold speed and report the same together with the location and time stamp information.
Thus, speed dependent scaling factors applicable per mobility state, as well as the parameters like NCR_M, NCR_H and TCRmax [6] can be optimized in the Network based on available measurements from the UE as captured in Table 3.
This information coupled with location and time of the measurement can provide information to the network to categorize if the problem is due to the speed of the UE. The measurement can be applied to the following use cases for SON [2]:-

- Coverage optimization: The network can semi-statically configure Speed dependent scaling factor, which control reselections. Thus, too many or too few reselections can be controlled.
- Mobility optimization: Speed dependent scaling factor in measurement control can be configured for the UE. Thus, issues of early and late handovers can be addressed.
- Parameterization for common channels: Random access transmission/retransmission parameters can be made speed dependent, if there are Random access failures reported in a specific mobility state.

3.3. Cause for Out Of Coverage

When the UE is switched on, the UE tries to camp on a cell using below mentioned steps:

- UE scans the available frequencies.
- Based on Received Signal Strength UE tries to synchronize to a cell.
- If synchronization is successful, UE tries to receive the Broadcast Information from the cell.
- Then if UE finds at least one acceptable cell then UE camps (normal camping or emergency camping) on the cell.

If any of the above steps fail for all the available cells, then the UE moves Out Of Service. Hence, there could be three possible errors in this case:

- No Frequency found in power scan
- Synchronization channels decode failure
- Broadcast channel decode failure
- No acceptable cell found (e.g. no cell from home and roaming PLMN is available)

UE detects and measures some neighbour cells in addition to the cells given by the network for reselection or handover purpose. Reselection procedure may fail because of either synchronization to neighbour cells fail or broadcast information reception from neighbour cells fail. This could lead UE to move into Out Of Coverage as serving cell goes below an acceptable threshold and no neighbour cell is scan results. In some networks, interference could be more though signal strength is good. This would leads to Synchronization channels/Broadcast channel decode failures
Thus, we propose to add the following the above-mentioned causes to be reported from the UE. This “Cause of out of coverage” parameter along with the time stamp, last camped cell and GPS position will provide network an option to adjust the transmit power levels on different synchronization/Broadcast channels. In addition, the network configuration can be updated based on above mention causes, thus assisting in the following use cases for SON [2].

- Coverage Optimization: During initial set up, the transmitted power on a cell for different channels (e.g. Synchronization channel/Broad Cast channel) may not be proper which may result in a situation where although Synchronization channel decoding is possible still UE is not able to get Broadcast channel information. Also, due to increase in number of customers or construction of some new building/flyovers it may possible that the interference has been increased a lot. This may result in a situation where UE is able to detect some good cells in power scan stage but due to interference, UE is not able to even decode the synchronization channel on those cells. Also in some remote areas, it is possible that UE is not at all able to get any frequency during power scan
- Common channel parameters: Network can reduce the interference in the common channels by increasing or decreasing the transmitted power levels.

4. Conclusion and Future work

The proposed schemes intend to highly scale up the functionality of Network Analytics in SON for cellular standards by incorporating new measurement quantities in the UE feedback which serve as the basis for enhancing network performance, coverage and capacity without human intervention thereby greatly alleviating the huge costs involved in O&M of the cellular networks. With the increased CAPEX for new RATs like 5G, the reduction on O&M is an important driver for keeping operators interested to maximize their return on investments. The theoretical ideas presented in this paper have to be applied to an implementation of SON using the ns-3 simulator to calculate quantified estimates of efficiency, effectiveness and RoI value.

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