Minimization of Drive Tests Solution in 3GPP

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ABSTRACT

Providing network coverage and quality of service (QoS) is an important task of a cellular network operator. This is because cellular spectrum is normally licensed under certain coverage obligations, and operators need to be competitive in market. To improve their networks, operators often send engineers in the field to collect radio measurements, to discover problems such as coverage holes in the network, and to determine whether certain parameter tuning is needed. However, such conventional "drive tests" require large Operation Expenditure (OPEX), while the collected measurements can only give limited snap shots of the entire network. In their Release 10 (Rel-10) specification, 3GPP studied and specified solutions to reduce this OPEX for drive tests, under the work item named "Minimization of Drive Tests (MDT)." The solution utilizes the user (customer) equipments (UEs) to collect field measurements, including radio measurements and location information. This article describes in details the solution adopted in 3GPP MDT; how they were developed and intended to be used.

INTRODUCTION

Conventional drive test is a manual process. To collect network quality information, an operator often needs to send engineers directly to the concerning area and obtain radio measurements in a hand-operated manner. Typically, a measurement vehicle, e.g., a van equipped with specially developed test terminals, measurement devices, and a Global Positioning System (GPS) receiver to obtain geographical location, is used to check coverage outdoors [1]. With such measurement vehicle, engineers would perform test calls in the car and record measurement results along the drive route. For indoor coverage engineers perform "drive tests" on foot, using specially developed measurement equipments that can be carried by hand. By analyzing these drive test results, the operator can take necessary measures to maintain and enhance the quality of the network, e.g., to decide whether to tune certain parameters or to deploy new base stations.

However, conventional drive tests consume significant time and human efforts to obtain reliable data, since typically, the obtained data only covers certain area of the network, e.g., roads and motorways. This has led to a huge amount of OPEX and delays in detecting problems on the network and in taking countermeasures. These problems have also been continuously discussed by the operators in the Next Generation Mobile Networks (NGMN) alliance, a non-standardization organization from where a consolidated operators' requirement for automated drive tests and recommendation solutions were delivered [2].

Driven by these problems and demands, operators proposed to standardize solutions in 3GPP to circumvent the cost for drive tests. In light of such necessity, a work item called "Minimization of Drive Tests (MDT)" was created in 3GPP in March 2009 [3] scoping two Radio Access Technologies (RATs), i.e., Long Term Evolution (LTE) and Universal Mobile Telecommunications System (UMTS). The main concept was to exploit commercial user equipments (UEs) – their measurement capabilities and geographically spread nature – for collecting radio measurements. The work item was finalized in March 2011 as part of 3GPP Rel-10 specification.

The key features of MDT defined in Rel-10 are as follows:
- The ability of the UE to include location information as part of the UE radio measurement reporting
- The ability of the UE to log radio measurements during the UE's idle state
- Reuse of radio measurements to those that anyway have to be performed as part of normal Radio Resource Management (RRM) procedures, thereby minimizing additional complexity and battery consumption by the UE.

We describe the use case that would benefit from MDT. We discuss two fundamental approaches to realizing MDT from architecture perspective. We explain in detail the functionalities and signaling procedures adopted in 3GPP Rel-10, and describe the security aspects.

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MDT USE CASES

The motives behind conventional drive test evolution drove further the need to understand possible scenarios, in which the foreseen solutions would help to minimize the drive tests. The main triggers for drive test execution are comprised of [1, 5]:

New base station deployment, where collection of downlink/uplink (DL/UL) coverage measurements of the new cell and neighbor cells are essential for a 'coarse' tuning of the network.

Construction of new highways/railways/major buildings, which are in fact new obstacles causing additional shadowing in the existing radio network and new sources of network traffic. Drive tests are performed to check whether coverage or throughput requires improvement.

Customer's complaint — when customers experience bad QoS and indicate these concerns, the operator performs measurements collection in the relevant area. This allows operators to identify, understand and solve the problem, and provide in effect high-quality service to the end user.

Periodic drive tests — regular network monitoring helps to reflect the actual performance of "alive" networks, with always changing due traffic conditions, and identify areas for improvement. This kind of drive tests is also performed on a regular basis to perform benchmarking between operators.

The solutions developed in Rel-10 focus on the Coverage Optimization use case that will benefit operators especially in the early phase of network deployment [6, 8]. The solutions enable collection of a set of MDT measurements that will provide information for the operator to design reliable coverage maps and consequently to detect coverage issues. The objectives for measuring coverage are as follows:

Coverage mapping: concerns the collection of MDT measurements in all parts of the network to provide an insight into the signal levels distribution per physical location and allow overall coverage visualization

Coverage hole and weak coverage detection: concerns areas where the downlink signal (of both serving and neighbor cells) is below the level needed to maintain either basic service or to fulfill planned performance requirements therefore causing discontinuous or poor service to the end user

Pilot pollution detection: concerns areas where large overlap of different cells' coverage or unexpected signal propagation between cells cause excessive interference levels, high power levels, high energy consumption, and low cell performance

Overshoot coverage detection: concerns areas where coverage of a cell reaches far beyond what was initially planned

Uplink coverage verification: concerns the detection of areas with poor uplink communication and unbalanced coverage between the uplink and downlink connections

In all the cases above, the MDT information should enable to detect overall network coverage as well as reveal the locations where signal levels are the weakest and embed a risk for degradation of end user experience.

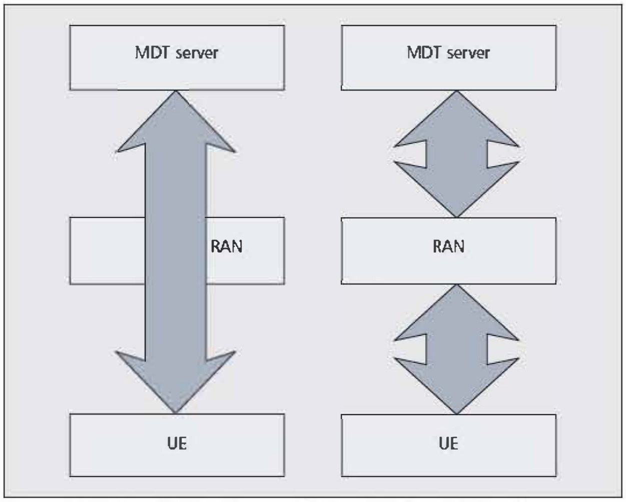

Figure 1. *U-plane MDT architecture (left) and C-plane MDT architecture (right).*

MDT ARCHITECTURE

INITIAL STUDIES (C-PLANE VS. U-PLANE)

In the first phase of the study in 3GPP, the following two architecture solutions were discussed [5]: Control-plane (C-plane) based MDT architecture and User-plane (U-plane) based MDT architecture. Figure 1 illustrates the two architectures. The C-plane based MDT architecture refers to an architecture where C-plane signaling is used for sending MDT configuration to the UE and for reporting MDT measurements to the network. In this architecture, the collected MDT measurements are visible to the Radio Access Network (RAN) node and Operation and Maintenance (OAM). On the other hand, U-plane based MDT architecture utilizes a certain application terminated directly between the UE and the MDT server. The application data, which may include measurement results and their reporting configuration, policy setting, etc., is transported using a U-plane bearer. One of the foreseen applications was Open Mobile Alliance – Device Management (OMA-DM). Since OMA-DM is terminated between the UE and OMA-DM server within the operator's network, the RAN node is unaware of the MDT measurements sent between the UE and OMA-DM server.

The conclusion of the study phase was that 3GPP specification work is to be continued based on C-plane MDT architecture. The main reason was the visibility of the collected MDT measurements in the RAN node such that the MDT information can be used by the RAN itself to perform any automated network parameter optimization. In fact the work on MDT in 3GPP was closely related to the work item for Self-Organizing Networks (SON) [4], to avoid any redundant features and to enable close interworking between the two features.

Nevertheless, 3GPP noted that the informa-

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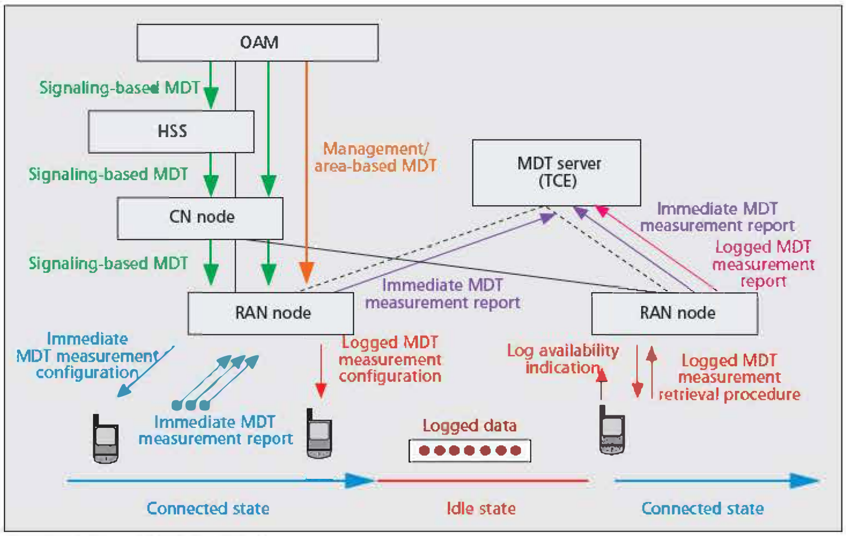

Figure 2. *Overall MDT architecture.*

tion elements defined for MDT configuration and measurements in the C-plane architecture can be utilized by other protocols/specifications outside 3GPP, e.g., OMA-DM.

REL-10 MDT ARCHITECTURE

Figure 2 describes the overall MDT architecture defined in 3GPP Rel-10 for LTE. The same architecture applies for both LTE and UMTS. Note that in the entire article, the terminology "RAN node" refers to "Evolved Node B (eNB)," i.e., base station in LTE, and "Radio Network Controller (RNC)," i.e., radio resource controller node in UMTS. The terminology "Core Network (CN) node" refers to "Mobility Management Entity (MME)" in LTE and "Serving General Packet Radio Service (SGSN)" or "Mobile services Switching Center (MSC)" in UMTS.

MDT is always triggered by the network, i.e., OAM decides the configuration of MDT parameters that need to be performed by the UE and sends these parameters to the RAN node for MDT activation. Upon reception of these MDT configuration parameters, the RAN node activates the MDT functionality in the UE by sending the MDT configuration parameters to the UE. After the UE performs relevant measurements, the UE reports the measurement results to the RAN node, which will then send these results to an MDT server, known as Trace Collection Entity (TCE).

For (inter-node) network signaling purposes, the existing Trace procedures (i.e., procedure for OAM to trace radio measurements in the RAN node defined in previous 3GPP Releases) were reused and extended for managing MDT measurements and configuration [8]. For radio interface signaling purposes, specific procedures and information elements were defined to support MDT configuration and reporting.

From network signaling perspective, two types of MDT were defined [8]:

Signaling-based MDT is used to collect measurements from a certain/specific UE. The so-called "signaling-based trace" feature [8] is used for managing signaling-based MDT.

Management/area-based MDT is used to collect measurements from randomly chosen UEs or a group of UEs that enter a (certain) geographical area. In management/area-based MDT the so-called "management-based trace" or "cell trace" feature [8] is used to manage MDT.

From radio configuration perspective, two types of MDT were defined [6]:

Logged MDT is a type of MDT where the UE stores the collected data for a certain period of time before the data is reported to the network. This type of MDT is performed when the UE is in idle state (i.e., the UE has no setup connection with the RAN node).

Immediate MDT is a type of MDT where the UE promptly reports the collected data to the network. This type of MDT is performed when the UE is in active state (i.e., the UE has a setup connection with the RAN node).

The standard allows any combinations between the above MDT types. For example, the management/area-based MDT can assign the UE to perform logged or immediate MDT, and the signaling-based MDT can be used also to assign the UE to perform logged or immediate MDT.

MDT CONFIGURATION FROM OAM TO RAN

SIGNALING-BASED MDT

Figure 3 illustrates an example scenario how MDT is activated to the UE in signaling-based MDT [8].

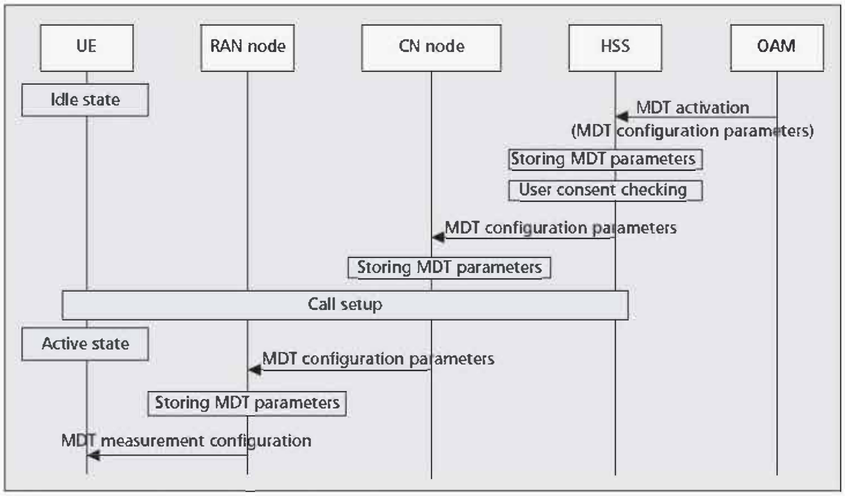

Figure 3. *Signaling-based MDT activation procedure.*

The MDT configuration parameters are sent from the OAM directly to the RAN node, and the RAN node stores these parameters for later configuration towards UEs. This type of MDT is activated typically in RAN nodes of a specific area, where the area is identified by a list of cells or paging location area identities.

In signaling-based MDT, UE selection is performed in the OAM based on a permanent UE identity, which uniquely identifies the UE in the network, such as International Mobile Subscriber Identity (IMSI) or International Mobile Equipment Identity and Software Version (IMEI SV). From OAM the MDT configuration parameters are sent to the Home Subscriber Service (HSS), where decision is taken whether MDT can be activated for a UE, based on whether the corresponding end user has consented to contribute to MDT. The HSS performs MDT activation towards the relevant CN node, e.g., MME in case of LTE. This activation is typically done when the UE initially attaches to the network or updates its paging location area, but the MDT configuration parameters can be propagated also as a standalone procedure at any time. This activation of MDT from CN to RAN is performed when a call or session is established.

MANAGEMENT/AREA-BASED MDT

The procedure used for activating MDT in management/area-based MDT is shown in Fig. 4 [8]. The MDT configuration parameters are sent from the OAM directly to the RAN node, and the RAN node stores these parameters for later configuration towards UEs. This type of MDT is activated typically in RAN nodes of a specific area, where the area is identified by a list of cells or paging location area identities.

One of the differences between signaling-based MDT and management/area-based MDT is how the UE selection is performed. In management/area-based MDT, selection of UEs to commit to MDT is done by the RAN node, based on the received parameters from OAM, UE radio capability, and the "MDT allowed flag" received from the CN node during call setup. This flag is set by the CN node based on the UE's roaming status and whether the corresponding end user has consented to participate in MDT. Roaming users and not-consented users are excluded from any MDT campaign.

MDT CONFIGURATION FROM RAN TO UE

LOGGED MDT

In logged MDT, measurements are configured to the UE "in advance," i.e., the received MDT configuration is stored in the UE and becomes only valid when the UE releases the connection and enters idle state [6]. The logging operation itself is therefore performed by the UE in idle state. For the UE to log MDT measurements, the UE must be able to detect, track, and measure radio signals from base stations, i.e., the signal level has to be above the UE receiver sensitivity. Once the signal level from all cells has dropped below the minimum level for camping, the UE encounters a "coverage hole." To save the amount of data, the UE performs no logging while in a coverage hole. The UE sensitivity would be inferior compared to specialized equipment in conventional drive tests, as such equipment is normally designed to have higher sensitivity and accuracy in measuring low level signals. However, in MDT the UE has the ability to log measurements for a period of 10 s in LTE (or 12 s in UMTS) from the time the UE enters a coverage hole.

By statistically analyzing these measurement logs, an operator can detect nearly where the coverage hole is. Such information would also provide a hint how to improve coverage, e.g., which base stations need parameter adjustments and which base stations would become neighbors if a new base station is placed on the dark spot. If the operator has other carrier frequencies or systems that cover the area, handover thresholds can be adjusted such that inter-frequency or inter-system handover can be triggered before

The RAN node is not required to retrieve the logged data directly after the log availability is received from the UE. The RAN node can initiate data retrieval at any time while the UE is connected. Hence, the UE is required to keep the non-retrieved report for 48 hours from the moment the logging duration timer expires.

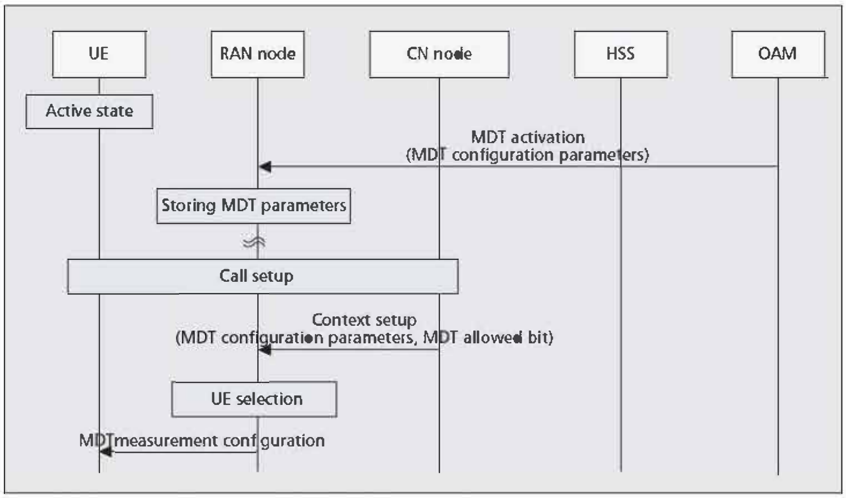

Figure 4. *Management/area-based MDT activation procedure.*

the UE enters the coverage hole. The logged measurements would allow the operator to decide which base stations need such parameter tuning.

The overall principle of logged MDT operation is illustrated in Fig. 5. The measurement configuration for logged MDT sent from the RAN node to the UE is created based on the MDT configuration parameters received from OAM [7, 8]. The followings are the configuration parameters:

- Logging interval which defines the periodicity of the measurements that should be logged
- Logging duration which determines how long the logged MDT configuration is valid
- Trace Reference which identifies the Trace Session used for the MDT
- Trace Recording Session Reference which is used together with the Trace Reference for correlating the collected log data of an MDT session and the UE
- TCE ID identifies the TCE to where the MDT measurements should be sent. This parameter is sent back by the UE within the log data to the network.

The measurement results are tagged with available location information, i.e., location information that happened to have been acquired by the UE at the time of measurement.

The UE stores the received configuration regardless of a state change (idle to active and vice versa) within the logging duration timer. This applies also for a change of camped operator network, i.e., Public Land Mobile Network (PLMN) and RAT (i.e., LTE and UMTS). In case of PLMN, RAT or state change, the logging by the UE is suspended. Effectively, logged MDT will resume when the UE returns to idle state or comes back to the RAT that configured MDT. The UE maintains only one logged MDT configuration (i.e., one MDT context) at a time. Thus, if other RAT or PLMN provides a new logged MDT configuration to the UE, the UE overwrites the previously received configuration.

The UE reports the logged data upon request from the network. The RAN node requests reporting based on indication from the UE, upon connection establishment, of the availability of logged data. The RAN node is not required to retrieve the logged data directly after the log availability is received from the UE. The RAN node can initiate data retrieval at any time while the UE is connected. Hence, the UE is required to keep the non-retrieved report for 48 hours from the moment the logging duration timer expires. The 48-hour timer can also be started when the logged data volume exceeds the available storage space in the UE reserved for MDT purposes. A UE supporting Rel-10 MDT is equipped with a minimum of 64 kB memory for log storage.

With this reporting mechanism, the amount of signaling is reduced compared to immediate MDT, as the UE reports all logs in one report. However, logged MDT requires additional memory for log storage and specific procedures for log reporting.

IMMEDIATE MDT

Immediate MDT utilizes procedures defined for RRM in previous 3GPP Releases to a great extent. The RAN node translates the MDT configuration parameters received from the OAM/CN node into RRM measurement configuration before sending to the UE [7, 8]. The main change introduced for immediate MDT was the configuration and reporting of location information. The followings are the configuration parameters:

- List of measurements which identifies what measurements the UE should collect

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