3GPP TR 36.805 V9.0.0 (2009-12)

Technical Report

3rd Generation Partnership Project;
Technical Specification Group Radio Access Network;
Study on Minimization of drive-tests
in Next Generation Networks;
(Release 9)

Keywords

<keyword[, keyword]>

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Foreword

This Technical Report has been produced by the 3rd Generation Partnership Project (3GPP).

The contents of the present document are subject to continuing work within the TSG and may change following formal TSG approval. Should the TSG modify the contents of the present document, it will be re-released by the TSG with an identifying change of release date and an increase in version number as follows:

Version x.y.z

where:

x the first digit:

1 presented to TSG for information;

2 presented to TSG for approval;

3 or greater indicates TSG approved document under change control.

y the second digit is incremented for all changes of substance, i.e. technical enhancements, corrections, updates, etc.

z the third digit is incremented when editorial only changes have been incorporated in the document.

1 Scope

The present document is intended to capture findings produced in the context of the Feasibility Study on Minimization of Drive-Tests (MDT) in next generation networks.

The study aims at assessing the feasibility, benefits and complexity of automating the collection of UE measurements to minimize the need of manual drive-tests. The work under this study should take the following steps.

1. Define use cases and requirements for minimizing drive tests in next generation LTE/HSPA networks

2. Based on the defined use cases and requirements, study the necessity of defining new UE measurements logging and reporting capabilities for minimizing drive tests and analyse the impact on the UE

Policy control mechanism and transport mechanism (including message syntax) for the new UE measurement logging and reporting capabilities are outside of the scope of the study. The study should focus on new logging and reporting capabilities for measurements already available at the UE.

2 References

The following documents contain provisions which, through reference in this text, constitute provisions of the present document.

- References are either specific (identified by date of publication, edition number, version number, etc.) or non-specific.
- For a specific reference, subsequent revisions do not apply.
- For a non-specific reference, the latest version applies. In the case of a reference to a 3GPP document (including a GSM document), a non-specific reference implicitly refers to the latest version of that document *in the same Release as the present document*.

[1] 3GPP TR 21.905: "Vocabulary for 3GPP Specifications".

[2] 3GPP TR 41.001: "GSM Release specifications".

[3] 3GPP TR 21 912 (V3.1.0): "Example 2, using fixed text".

[4] 3GPP TS 25.331:"Universal Terrestrial Radio Access (UTRA); Radio Resource Control (RRC); Protocol specification".

[5] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) protocol specification".

[6] R2-096049 MDT coverage and capacity optimization.

[7] R2-096737 Further simulations on network based solutions for coverage optimization.

[8] R2-095910 Simulation results for MDT logging with UE under RLF.

[9] R2-097031 MDT uplink coverage optimization.

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given in TR 21.905 [1] and the following apply. A term defined in the present document takes precedence over the definition of the same term, if any, in TR 21.905 [1].

Definition format (Normal)

<defined term>: *<definition>.*

example: text used to clarify abstract rules by applying them literally.

3.2 Symbols

For the purposes of the present document, the following symbols apply:

Symbol format (EW)

<symbol> <Explanation>

3.3 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [1] and the following apply. An abbreviation defined in the present document takes precedence over the definition of the same abbreviation, if any, in TR 21.905 [1].

Abbreviation format (EW)

<ACRONYM> <Explanation>

4 Requirements and constraints

The solutions for the minimisation of drive tests shall comply with the following requirements.

1) **UE measurement configuration**
The operator shall be able to configure the UE measurements for the UE logging purpose independently from the network configurations for normal RRM purposes.

2) **UE measurement collection and reporting**
Measurement logs usually consist of multiple events and measurements taken over time. A real time reporting of a measurement log at every measurement logging trigger is not necessary. The time interval for measurement collection and reporting shall be separately configurable in order to limit the impact on the UE battery consumption and network signalling load. It shall be possible to collect measurement logs preceding a particular event (e.g. radio link failure).

3) **Geographical scope of measurement logging**
Drive testing of a targeted geographical area (e.g. problem area) is part of usual activities for operators. It shall be possible for the operator to configure the geographical area where the defined set of measurements shall be performed. Some measurements (e.g. the continuous logging function) might run independent of any geographically defined area.

4) **Location information**
The measurements in measurement logs shall be linked to available location information and/or other information or measurements that can be used to derive location information.

5) **Time information**
The measurements in measurement logs shall be linked to a time stamp that is available in the UE. Accuracy of time information (absolute time, relative time) is FFS.

6) **Device type information**
The terminal used for measurements shall be able to indicate a set of terminal capabilities which allows the network to carefully select the right terminals for specific measurements. It is FFS if existing UE capability reporting is sufficient.

7) **Dependency on SON**
The solutions for minimization of drive tests shall be able to work independently from SON support in the network.

The solutions for the minimization of drive tests shall take into account the following constraints.

1) **UE measurements**
The UE measurement logging mechanism is an optional feature. In order to limit the impact on UE power consumption and processing, the UE measurement logging should as much as possible rely on the measurements that are available in the UE according to radio resource management enforced by the access network.

2) **Location information**
The availability of location information is subject to UE capability and/or UE implementation. The solutions requiring the location information shall take into account power consumption of the UE due to having to run its positioning components.

5 Use cases

5.1 Coverage 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, common channel parameterization), as well as backend network management activities, such as network dimensioning, CAPEX/OPEX planning and marketing. Additionally the detection of coverage problems (e.g. coverage holes, pilot pollution, low user throughput, etc.) in specific areas is performed, e.g. based on customers complaints, along roads or train lines, in case of special events.

Coverage is something that a customer can easily notice through the terminal UI (i.e. out-of-service area indication), and is a major criteria that a customer considers when comparing service provided by different operators. With the increase in data service provision, DL throughput is also an important criterion by which many customers judge the performance of the network (either by observing download time or by reading review articles written by mass media). Poor UL coverage will impact user experience in terms of call setup failure / call drop / poor UL voice quality.

Accordingly, it is very important for operators to be aware of the coverage / throughput their networks provide, and rigorous “drive tests” are performed to collect such information.

The main triggers for operators to perform drive tests to collect network performance metrics in their network are outlined below. If these measurements can be collected from UEs within the framework of Drive test minimisations, the rigorous drive tests explained below can be reduced, which will significantly reduce network maintenance costs for operators, ensure faster optimisation cycle resulting in higher customer satisfaction and nonetheless help to reduce the carbon emission to protect the environment. Furthermore, it will enable operators to collect measurements from areas which are not accessible for drive tests (e.g. narrow roads, forests, private land/house/office).

1) Deployment of new base stations / cells

This is the first phase of drive test that is performed for a particular cell / smaller network area.

When new base stations / cells are deployed, drive tests are performed before and after service activation of the new cell. Specifically speaking, first, radio waves will be transmitted from a new cell in a “test mode” (i.e. cell barred for normal access classes), and initial collection of DL/UL coverage measurements of the new cell and neighbour cells will be made in the intended area of coverage improvement. During this phase, initial area tuning is performed (e.g. selection of an appropriate antenna for the new cell, adjustment of antenna tilting of the new cell and neighbour cells, etc.). Service with the new cell will be started after such initial tuning. However, drive tests are continued to collect more extensive data of DL/UL coverage measurements in the intended area to make sure good DL/UL coverage is being provided. Further area tuning will be performed during this phase as necessary.

Deployment of new base stations / cells is a continuous / long lasting process for a new system, but also established systems need continuous redesign and extension. This trend is becoming more and more apparent now that there are many RAN elements to fine tune coverage of the operator’s network (e.g. Remote Radio Heads, picos, femtos).

2) Construction of new highways / railways / major buildings

This is the additional phase of drive test that is performed for a particular cell / smaller network area in an event driven manner.

Areas where new highways / railways / major buildings are constructed are potential areas which residing population will increase, and are important areas to provide good coverage. Also, such large constructions normally introduce weak pilot areas as they become new sources of shadowing losses. Therefore, whenever new highways / railways / major buildings are constructed, operators perform drive tests in the relevant area to see if the coverage needs to be improved. If coverage improvement is deemed as necessary, operators take action by deploying new cells, adjusting antenna tilting of existing cells, etc. Drive tests to collect performance metrics are performed again after such actions to check that coverage has improved in the area to an adequate level.

3) Customer's complaints

This is another additional phase of drive test that is performed for a particular cell / smaller network area in an event driven manner.

Customer's complaints are an important trigger to perform drive tests. When customers indicate coverage / throughput concerns (e.g. poor DL coverage at their home, office, etc.), operators perform "drive tests" in the relevant area to observe the coverage quality. If coverage improvement is deemed as necessary, operators take action by deploying new cells, adjusting antenna tilting of existing cells, etc. Drive tests to collect performance metrics are performed again after such actions to check that coverage has improved in the area to an adequate level.

4) Periodic drive tests

This is the additional phase of drive test that is performed for a particular cell / smaller network area or the entire network in a regular and on demand manner.

DL/UL coverage is affected when new constructions (or destruction) are performed due to shadowing loss changes. As indicated in 2), operators are conscious of major constructions and perform drive tests around such area in a timely manner. However, operators cannot follow each and every construction, especially for smaller scale constructions. Therefore, it is important for operators to periodically perform drive tests in order to update their understanding of the coverage levels provided in their networks. If coverage improvement is deemed as necessary after such periodic drive tests, operators take action by deploying new cells, adjusting antenna tilting of existing cells, etc. Drive tests to collect performance metrics are performed again after such actions to check that coverage has improved in the relevant area to an adequate level. This kind on drive tests is also performed on a regular basis to perform benchmarking between operators.

5.2 Mobility optimization

Mobility optimization is an important part of network operation. Information about mobility problems or failures can be used to identify localized lack of coverage or the need to adapt the network parameters setting, e.g. in order to avoid too early or too late handover and to improve the handover success rate and overall network performance.

5.3 Capacity optimization

The operator needs to be able to determine if there is too much/little capacity in certain parts of the network i.e. to detect locations where e.g. the traffic is unevenly distributed or the user throughput is low. This helps to e.g. determine placement of new cells, configure common channels and optimize other capacity related network parameters.

5.4 Parameterization for common channels

User experience and/or network performance can be degraded by suboptimal configuration of common channels (e.g. random access, paging and broadcast channels). Detecting problems (e.g. on UL or DL common channel coverage) or analyzing the performance (e.g. connection setup delay) for the procedures associated with common channels, helps network parameter setting and configuration change for system performance optimization, (e.g. RACH channel parameters are set as a trade off between congestion and capacity)

5.5 QoS verification

One of the objectives of the network performance analysis is the verification of the quality of service (e.g. user throughput). This also allows detecting critical conditions and determining the need to change the network configuration, parameter settings or capacity extension.

This aspect is important also in the initial deployment of a new radio access technology, in order to check if the quality of service experienced by the end user is in line with the performance target defined in the planning strategy and more in general to test the overall performance of the technology along the subsequent deployment phases.

Traditionally the first step is to verify the coverage, possibly also in indoor and the reliability of the mobility procedures (e.g. railways and highways). However since the introduction of HSPA, the verification of the quality of service in a way that allows to correlate with the user experience, e.g. in terms of user throughput has become an important KPI, also in the first phase of the network deployment. This will be even more important for LTE where the mix of different type of service classes scheduled on the same radio resources will happen very soon.

The reasons for un unexpectedly low QoS may be different, e.g. coverage, load or user mobility. Moreover the problem may occur at the border region of several cells or localized in the cell due to particular propagation conditions or uneven traffic distribution. Only looking at the cell level statistics is not an effective way to understand the origin of the problem and take the proper actions (e.g. whether to increase the coverage, the capacity or to change the RRM settings)

The verification of the QoS is a crucial task of the current drive test campaigns; moreover, in order to provide a reliable statistical analysis of this kind of performance, extensive drive test should be performed with huge costs for the operator.

The possibility to periodically collect such measurements, even if for short periods and on a limited number of UEs, would be more cost effective and more reliable from the statistical point of view. Moreover, the possibility to collect the measurements by the UE increases the “coverage” of the analysis, as it is possible in inaccessible areas or in indoor, i.e. where a considerable portion of the traffic is generated.

6 UE measurements

General principles for UE measurement logging are captured in the following. The UE measurement logging function is a UE optional feature and some measurements may or may not be available in the UE as indicated below.

While defining the measurement logs and the need for those, it shall be considered how normal existing reporting principles through RRC signalling can be utilized in order to collect appropriate information for a given use case. The available RRC measurements and SON measurements, potentially with some additional reporting and/or together with (e)NB measurements, may be enough to supply the measurement logs identified for particular target use cases. This shall be used as benchmark when assessing the need and/or value for new functionalities and reporting in the scope of this Study Item.

If the new functionality is defined, it is beneficial to evaluate its usability in terms of SON.

Basic model / principles

The network can request the UE to perform some logging of measurements. The UE executes the logging as requested by the network with certain constraints, e.g. location information availability. Reporting of UE measurement log can be separately configured. Period of logging and that for reporting can be different.

Radio environment measurement (aka. cell measurements)

While measurements for the measurement logging are configured based on OAM requirements, the availability of those measurements is under control of RRM in the access network. It is however expected that that relevant measurements would be available for a certain period before and after a concerned event where the measurements need to be logged. It is therefore considered that as a baseline, the UE does not have to perform additional radio environment measurements for measurement logging purposes. The need for additional radio environment measurements shall be motivated case by case.

Location information

The extensive use of positioning component of the UE shall be avoided since it would significantly increase the UE power consumption. It is expected that the availability of location information depends on the UE implementation and/or capability.

6.1 UE measurement logging

In the following subsections, UE measurement logs for minimizing drive tests are described. Measurement logs are taken at the occurrence of predefined "triggers" (e.g. periodic trigger, a failure event). A UE log can consist of basic components captured in the previous section and/or records of events themselves.

6.1.1 Periodical downlink pilot measurements

Description:

Radio environment measurements, such as CPICH RSCP, CPICH Ec/No, or TDD P-CCPCH RSCP and ISCP, RSRP and RSRQ (connected mode only) are logged periodically.

Benefits:

This measurement log corresponds to the use case "coverage optimization".

The main measurements collected by operators to be aware of the DL coverage / achievable throughput are the DL common pilot reception levels and SIR levels.

Existing RRM measurements mainly rely on the event triggered measurement reporting and periodical reporting is only configured on demand. Also there are a number of restrictions.

- There is no accompanying location information. Even though the operator can identify cells with DL coverage problems, operators would still need to perform drive tests to figure out the problematic area in the cell as the exact location on where the low DL common pilot reception levels / SIR levels are being experienced is not known from existing RRM mechanisms.

- The existing RRM mechanisms only allow for measurements to be reported when the UE has RRC connection with the particular cell, and there is sufficient UL coverage to transport the MEASUREMENT REPORT. This will restrict measurements to be collected from UEs not experiencing RLF and experiencing sufficient UL coverage.

Detailed measurement info:

Trigger type: Periodical Triggered when configured periodical timer expires.		
Configuration parameter(s): - Periodic timer - The number of logging		
Measurement	**Definition**	**Remarks**
Location info	▪ Location at which concerned trigger took place	
Time info	▪ Time at which concerned trigger took place	
Cell Identification	▪ CGI of the serving / current cell at which concerned trigger took place ▪ PCI/PSC of other cells for which measurement is logged	Availability of CGI for HSPA is FFS
Radio environment measurement	▪ Cell measurements that are available at the trigger	

6.1.2 Serving Cell becomes worse than threshold

Description:

Radio environment measurements, such as CPICH RSCP, CPICH Ec/No, or TDD P-CCPCH RSCP and ISCP, RSRP and RSRQ (connected mode only), are logged when the serving cell metric becomes worse than the configured threshold. A measurement logging window (i.e. "sliding window" in which collected logs are kept in the UE) is used in order to be able to collect information during a certain period before and after the occurrence of event.

Benefits:

This measurement log corresponds to the use case "coverage optimization".

If the operator is interested in a particular DL coverage problem, it is efficient to take measurement logs corresponding to the problem of their interest. The operator can translate their criterion (e.g. out of coverage) into the threshold in order to be able to find out problem areas. In order to identify the characteristics of the problem (e.g. happened in a particular mobility scenario), it is beneficial measurement logs provide information preceding the measurement logging trigger.

See 6.1.1.

Detailed measurement info:

Trigger type: Serving cell becomes worse than threshold

Triggered when a cell becomes worse than the preconfigured threshold.

Configuration parameter(s):

- Threshold
- Measurement logging window
- Measurement logging interval (within the measurement logging window)

Measurement	Definition	Remarks
Location	▪ Location at which concerned trigger took place ▪ Location at which concerned measurements took place	
Time stamp	▪ Time at which concerned trigger took place ▪ Time at which concerned measurements took place	
Cell Identification	▪ CGI of the serving / current cell at which concerned trigger took place ▪ PCI/PSC of other cells for which measurement is logged	Availability of CGI for HSPA is FFS
Radio environment measurement	▪ Cell measurements that are available at the occurrence of the trigger ▪ Cell measurements that are available during a certain period before and after the occurrence of concerned trigger	

6.1.3 Transmit power headroom becomes less than threshold

Description:

Transmit power headroom and radio environment measurements, such as CPICH RSCP, CPICH Ec/No, or TDD P-CCPCH RSCP and ISCP, RSRP and RSRQ (connected mode only) are logged when UE transmit power headroom becomes less than the configured threshold.

Benefits:

This measurement log corresponds to the use case "coverage optimization".

From observing UL transmit power levels, operators can spot areas of insufficient UL link budget and also deduce achievable UL throughput levels that can be provided in their networks. Collecting such information will help operators in fine tuning cell individual offsets, determining where to deploy new cells in the network, adjusting antenna tilting, etc. However, it should be noted that Power Headroom event based UE measurement without taking the resource allocation into account can result in unnecessary reporting depending on the PRB allocation.

It is possible for RAN to collect UL power headroom reports using already existing MAC procedures. However, there are a number of restrictions.

- There is no accompanying location information. Even though the operator can identify cells with UL coverage problems, operators would still need to perform drive tests to figure out the problematic area in the cell, as the exact location on where the poor UL quality is being experienced cannot be known from existing MAC procedures.
- With the existing UL power headroom reporting, eNB / NodeB can only collect information when there is sufficient UL link budget to ensure successful decoding of the MAC PDU carrying UL power headroom at the eNB / NodeB.
- For UMTS, UL power headroom reporting is only active when E-DCH is configured, i.e. UL power headroom cannot be collected in UMTS when only DCH has been configured.

Detailed measurement info:

Trigger type: Transmit power headroom becomes less than threshold Triggered when UE transmit power headroom becomes less than the preconfigured threshold.		
Configuration parameter(s): - Threshold - Measurement logging window - Measurement logging interval (within the measurement logging window)		
Measurement	**Definition**	**Remarks**
Location info	▪ Location at which concerned trigger took place ▪ Location at which concerned measurements took place	
Time info	▪ Time at which concerned trigger took place ▪ Time at which concerned measurements took place	
Cell Identification	▪ CGI of the serving cell at which concerned trigger took place ▪ PCI of other cells for which measurement is logged	
UE transmit power info	▪ UE transmit power	
Radio environment measurement	▪ Cell measurements that are available at the trigger ▪ Cell measurements that are available during a certain period before and after the occurrence of concerned	

	trigger	

6.1.4 Random access failure

Description:

Details on the random access and radio environment measurements, such as CPICH RSCP, CPICH Ec/No, or TDD P-CCPCH RSCP and ISCP, RSRP, and RSRQ (connected mode only) are logged when a random access failure occurs.

Benefits:

This measurement log corresponds to the use case "coverage optimization".

The cause of random access failure can be due to, e.g. a wrong transmit power setting or congestion. Detailed information about random access failure event shall be collected in order for the operator to analyse the characteristics of the random access failure. DL radio environment measurements, such as CPICH RSCP, CPICH Ec/No, RSRPand RSRQ (connected mode only), are also necessary because of the open loop control of the random access procedure relying on these DL metrics. Collecting such information will help operators in fine tuning random access parameters, adjusting antenna tilting, etc.

Occurrence of random access failure can not always be detected by the network through existing measurements. Relation to RACH measurements defined for SON is FFS.

Detailed measurement info:

Trigger type: Random access failure Triggered when a random access procedure failure occurs.		
Configuration parameter(s): - N/A		
Measurement	**Definition**	**Remarks**
Cause (FFS)	▪ List of the failure cause for each failed attempt	E.g. LTE: 'Random Access Response not received', 'Lost in contention resolution' UMTS: 'No ack on AICH', 'Nack on AICH received'
Random access configuration (FFS)	▪ Availability of dedicated preamble (LTE only)	Yes / No
Location	▪ Location at which concerned trigger took place	
Cell Identification	▪ CGI of the serving / current cell at which concerned trigger took place	Availability of CGI for HSPA is FFS
Radio environment measurement	▪ Cell measurements that are available at the occurrence of the trigger	

6.1.5 Paging Channel Failure (PCCH Decode Error)

Description:

Details of the radio environment, location, time and cell identity are logged at the point when the UE fails to decode the PCCH on the Paging Channel for X2 consecutive times (configurable by the operator even though it managed to successfully decode the PDCCH at each paging occasion.

Benefits:

This measurement log corresponds to the use case "parameterization of common channels'

In idle mode it is important for the operator to know whether the UE can reliably be reached by paging. If a user cannot be reached by paging, it will have a negative effect on the user experience (at least the calling party) and also on the operator revenue (through missed call opportunities). In current networks, drive tests are required to assess the UE's ability to receive paging messages within the coverage area of a cell. Since such activities result in high costs, it is beneficial if the UE could log occurrences of when it cannot decode the information on the paging channel together with other relevant information.

The ability to reach the UE in Idle mode depends on the UE being able to successfully decode the Paging Channel (PCH) for the Paging Control Channel (PCCH). Even if UE successfully decoded the PDCCH at its paging occasion, it does not necessarily imply that it will be successful in decoding the PCCH based on the allocated resources on PDCCH for the PCH. Inability to decode the PCCH might be due to incorrect parameter setting e.g. UE transmit power. Hence, recording of such an event will help operators identify the location/cell/time where such failure occurs and hence take actions to reduce the failure e.g. fine tuning of parameters for the PCH.

The PCCH makes use of the RLC TM mode and hence the eNB is not aware whether the paging message was correctly received or not. Thus, UE is in a better position to identify the event when it cannot acquire the PCCH. In order to increase the reliability of the logging activity it is desirable that UE only logs a failure after several consecutive PCCH decode errors occurs (which would indicate that there is a problem in a certain coverage area).

Detailed measurement info:

Trigger type: Paging Channel Failure (PCCH Decode Error) UE fails to decode PCCH consecutively for X1 times even though it managed to decode the PDCCH at its paging occasion.		
Configuration parameter(s): - Number of consecutive PCCH decoding failures at paging occasions where PDCCH was correctly decoded) to trigger event (X1)		
Measurement	**Definition**	**Remarks**
Location	▪ List of the failure cause for each failed attempt Location at which first PCCH decoding failure occurred and X1th PCCH decoding failure occurred at the paging occasion.	Since paging DRX can be relatively long, it is important to log the location of each failure.
Time stamp	▪ Time at which X1th PCCH decoding failure occurred	Since paging DRX cycle is known, the time at which first PCCH decoding failure occurred can be easily deduced
Cell Identification	▪ CGI (s) of cell (s) where PCCH decoding failure for paging occurred	
Radio environment measurement	▪ Average RSRP and RSRQ over time from first PCCH decoding failure to X1th PCCH decoding failure.	

6.1.6 Broadcast Channel failure

Description:

Details of the radio environment, location, time, cell identity and frequency are logged at the point when the UE fails to read the relevant DL common channels to acquire required system information for camping on a cell.

Benefits:

This measurement log corresponds to the use cases "coverage and capacity optimisation" and "parameterization of common channels'

Idle mode accessibility is an important measure of the network 'quality' and can be easily noticed by the user e.g. lack of coverage indicator on display. Although UE can detect the Synchronization Signal of a certain cell and get DL synchronization successfully, it does not mean that it will be able to camp on the cell. In order to do so, UE has to first acquire the relevant system information which will allow it to check its accessibility to the cell and also provide it with the necessary parameters to access the cell.

Since the system information is broadcast, there is no way for the eNB to become aware of the UEs that have reselected to a cell but were unable to camp on it due to inability to read its system information. In current networks, drive tests are used to assess whether UE can reliably acquire the relevant system information for camping. It is difficult for the operator to have confidence in the parameter settings of all DL common channels which are relevant for system information acquisition without carrying out extensive drive tests whose cost can be prohibitive. Operators usually only find out there is a problem when customer complaints are received and they have to adopt a reactive approach to solve the problem which is not ideal.

For LTE, in the process of system information acquisition, UE first has to successfully decode the P-BCH to acquire the MIB. It is important for the operator to know when UE cannot successfully decode the P-BCH, even though it has successfully synchronized to the cell. Inability to decode the P-BCH implies that UE cannot camp on it and hence cannot get service from the cell.

The MIB contains basic system parameters like system bandwidth and scheduling information which are required for UE to locate and acquire the other necessary system information broadcast on the DL-SCH. In order to limit the number of measurement logs, it can be assumed that if UE can successfully acquire SIB1 on the DL-SCH, then it would also be able to acquire the other relevant SIBs which are also broadcast on the DL-SCH with similar parameter settings.

Acquisition of SIB1 also depends on the UE's ability to correctly decode the PCFICH/PDCCH for SI-RNTI reading. Hence, it is important for UE to log cases when it fails to decode the PCFICH/PDCCH for SIB1 acquisition.

Detailed measurement info:

<table>
<tr><td colspan="3">Trigger type: Broadcast Channel failure
- Channel type P-BCH: UE fails to decode P-BCH consecutively for X2 times after selecting/reselecting a cell for camping
- Channel type PCFICH/PDCCH: UE fails to find SI-RNTI of SIB1 in the subframe #5 of radio frames for which SFN Mod 2 = 0 after X3 consecutive attempts after camping on a cell.
- Channel type DL-SCH for BCCH Transmission: UE fails to decode DL-SCH (for SIB1) for X4 consecutive attempts after camping on a cell even though PDCCH was correctly decoded.</td></tr>
<tr><td colspan="3">Configuration parameter(s):
- Maximum number of consecutive P-BCH decoding failures before event is triggered (X2).
- Maximum number of consecutive PCFICH/PDCCH decoding failure for SIB1 SI-RNTI (X3) before event is triggered.
- Maximum number of consecutive SIB1 decoding failures (even though PDCCH decoding was successful) before event is triggered (X4).</td></tr>
<tr><td>Measurement</td><td>Definition</td><td>Remarks</td></tr>
<tr><td>Channel type</td><td>▪ To indicate the broadcast channel type for which failure happens,. Channel type can be any of P-BCH, PCFICH/PDCCH, or DL-SCH for BCCH transmission</td><td></td></tr>
<tr><td>Location</td><td>▪ Location at which decoding failure occurs.</td><td>It is necessary to only log the location where the event is</td></tr>
</table>

		actually triggered e.g. after X2 P-BCH decoding failure, X3 PDCCH decoding failures or X4 DL-SCH decoding failures for SIB1.
Time stamp	▪ Time at which decoding failure occurred	It is necessary to only log the time when the event is actually triggered e.g. after X2 P-BCH decoding failure, X3 PDCCH decoding failures or X4 DL-SCH decoding failures for SIB1.
Cell Identification	▪ Cell selection/reselection: PCI of cell where decoding failure occurred ▪ Cell Reselection: Reference CGI	In case cell reselection occurs before triggering condition is reached, event (P-BCH decoding failure, PDCCH decoding failure fro SI-RNTI or DL-SCH decoding failure for SIB1) is triggered at cell reselection based on current failures and PCI of current cell before reselection is logged The reference CGI is the CGI of source cell before reselection attempt. This information can be used together with the PCI and frequency information to identify the location of the cell in case the explicit location information is not available.
Frequency	▪ Carrier frequency of cell where decoding failure occurred	The frequency information where decoding failure occurred
Radio environment measurements	▪ Average RSRP and RSRQ over time when P-BCH, PDCCH or DL-SCH (for SIB1) could not be decoded.	A moving average of RSRP/RSRQ over the last X2 P-BCH, X3 PDCCH decoding failures for SI-RNTI or X4 DL-SCH decoding failures for SIB 1 could be used.

6.1.7 Radio link failure report

Description:

Radio measurements, such as CPICH RSCP, CPICH Ec/No, or TDD P-CCPCH RSCP and ISCP, RSRP, and RSRQ available at the UE are reported at the RLF occurrence.

Benefits:

The ‘RLF report’ measurement corresponds to the “coverage optimization” use case.

The ‘RLF report’ can identify several problems originated from the coverage issue. Therefore, detection probability for a coverage hole by this measurement information is anticipated to be high in real networks. Moreover, often the issues related to DL common channel detection are evoked by coverage situation. The ‘RLF report’ provides means to solve the basic DL coverage issues and the measurements specifically targeted to common channel parameterization use cases can hence be focused mainly on adjusting the common channel parameters.

Collecting such information will help operators in finding coverage problems in specific areas and relieve their manual drive testing effort.

The merit of the proposed measurement information is also the that coverage optimization use case can be achieved by existing measurements accompanied with normal RRC signalling. The advantage, with regard to SON is that the same reporting can be used for SON coverage and mobility optimization, providing thus the input data for multiple purposes.

Detailed report info:

Trigger type: Radio Link failure Triggered when a radio link failure occurs.		
Configuration parameter(s): - Extended RLF reporting set ON/OFF		
Measurement	**Definition**	**Remarks**
Location info	▪ Location at which concerned trigger took place	Presence based on availability
Cell Identification	▪ The last cell ID, at which RLF took place	
Radio environment measurement	▪ Cell measurements that are available at the occurrence of the trigger ▪ PCI/PSC of other cells for which measurement is logged	

6.2 UE measurement Reporting

Various reporting criteria can be considered depending on the measurement or use case. Realtime reporting and/or non-realtime reporting can be required. Further analysis is required in WI phase.

7 Impact analysis

The analysis provided in this section is more qualitative rather than quantitative, but could be interpreted as guidelines to consider during the WI phase.

7.1 UE impact

7.1.1 UE power consumption

UE measurements:

1. **Availability of MDT measurements during Active mode**

Even though the principle of minimisation of drive tests is to use existing measurements and information already available to UE as much as possible, the UE might need to perform and store additional measurements to fulfil the MDT use cases.

Unless normal RRM based measurement reporting is enough, storing of past measurement results seems to be necessary so that measurement results prior to events of interest can be reported.

This implies additional functionality in the UE which should be analysed per use case, in order to understand the additional complexity and power consumption introduced.

2. Idle mode and DRX impact on MDT measurements

It is assumed that the basic requirements which are already applicable to radio resource management (RRM) measurements should also be applicable to measurements which are reported for MDT purposes. For example,

- Detailed requirements (e.g. such as accuracy) for measurements in idle mode should not be specified, similarly to existing UE idle mode measurements
- The MDT measurement regime should facilitate as much as possible that measurements may be performed during the “on” part of the DRX cycle, both in idle mode or in connected mode
- If UE needs to perform additional measurements for MDT purposes compared to the measurements performed for the normal RRM purposes, UE power consumption might be increased. Especially additional measurements of inter-RAT or inter-frequency cells can have increased power consumption impacts in idle mode or DRX connected state. Additional intra-frequency measurements when the serving cell is strong (i.e. serving cell signal level is higher than threshold requiring intra-frequency measurements) can also have a power consumption impact.

3. Availability & Accuracy of positioning information at UE

As indicated in section 4, the availability of location information is subject to UE capability and/or UE implementation. The solutions requiring the location information shall take into account power consumption of the UE due to having to run its positioning components. If for MDT, the UE is only required to report already available location information, i.e. no additional positioning calculations solely for the purpose of MDT, then additional UE power consumption due to the MDT requirement to provide location information is minimized/negligible. The required accuracy for location information would be dependent on the MDT use case and as there is post processing of reported MDT measurements the accuracy of positioning information does not always have to be of high accuracy .

The MDT functionality should not result in long active periods of the positioning function in the UE in order to avoid high UE power consumption. For example, requiring the UE to anticipate the occurrence of a certain MDT measurement trigger, and to perform positioning calculation prior to the actual occurrence of the trigger can be problematic for certain MDT measurement triggers as the waiting time for the trigger to happen can be arbitrarily long (in principle of any length).

<u>UE measurement reporting:</u>

If RRM measurements and reporting and reporting for normal operations utilized for mobility are used for MDT, then no impact to UE is seen.

<u>UE logging and non realtime reporting:</u>

Logging and storing an excessive amount of measurements in the UE baseband/L2 entity is probably not feasible, and is thus expected to require forwarding/storing/retrieval of measurements to/at/from another entity (e.g. external device) within the UE. Such interactions with external devices will also impact UE power consumption, and should not be neglected when considering non realtime reporting..

7.1.2 UE memory impact

If immediate reporting is utilized for MDT measurement reporting (e.g. using normal RRC reporting or even with error event triggered reporting e.g. “RLF report”) the additional UE memory impact is seen negligible.

On the other hand, independent logging triggers and reporting triggers suggest that the UE is required to store measurements that it has acquired until those measurements get reported to the network. I.e., the UE has to be equipped with memory that can accommodate measurement logs during the time measurement reporting is not performed. Otherwise, measurement logs will be discarded before being reported.

The following is an example showing the required UE memory in supporting “Periodical downlink pilot measurements”, in the case a UE is required to log the measurement every 2 seconds for a total time of 24 hours before a report is sent.. Note that some of the parameters are E-UTRA specific, but the number of encoded bits is the same thanks to the following correspondence, PCI = PSC (9 bits), RSRP = CPICH RSCP (7 bits), RSRQ = CPICH Ec/No (6 bits).

Parameters	**Size**
Location information (Latitude / Longitude / Altitude) as per [TS23.032]	63 bits
Time information (Month / Day / hour / Minute / Second) as per [TS24.008] and [23.040]	40 bits
CGI of the serving cell (PLMN-id + Cell-id)	52 bits
PCI of neighbour cells (x 32)	288 bits
Radio environment measurement (RSRP / RSRQ) for serving cell + neighbour cells (x32)	429 bits
Total number of bits per log	872 bits
Total size of logs collected every 2 seconds for 24 hours	Around 4.7 Mbytes

Compared to size of memory now considered for normal L2 activity, the required memory size becomes extremely large. However, if the memory where the logs are stored is located in an external device, then the severity of memory impact will be smaller. Additionally proper configuration of MDT measurement (i.e. lower logging frequency and higher reporting frequency) can mitigate the afore-mentioned impact.

7.2 End user impact

From the end user perspective one should consider at least following points when making the final decision regarding MDT measurements/architecture:

- Power consumption
    - The power consumption could become a problem visible to the end user. See chapter 7.1.1 for more details.

7.3 Other impact

8 Conclusion

The following main conclusions were drawn in the study from the requirements for Minimization of Drive Tests.

1. MDT use cases: The most important use case for operators initially is on coverage optimisation; therefore the work on MDT should focus on this use case.
2. MDT measurements: Following UE measurements (or similar functionality) are considered with focus for this use case:
    - Periodical downlink pilot measurements
    - Serving Cell becomes worse than threshold
    - Transmit power headroom becomes less than threshold
    - Paging Channel Failure (PCCH Decode Error)
    - Broadcast Channel failure

3. MDT measurement location association: In order to allow (i.e. during operator post-processing) the association between MDT measurements and position where the MDT measurement was taken, available positioning information in the UE is reported to the network together with the MDT measurement results.

4. MDT measurement time association: In order to allow (i.e. during operator post-processing) the association between MDT measurements and time when the MDT measurement was taken, time stamping for the MDT measurements is added by the UE if it cannot be determined by the network (e.g. immediate reporting). This timestamp does not need to be very accurate.

The following two methods are evaluated for collection of UE measurements in the study of minimisation of drive tests. Some simulations were carried out as part of the study and results are summarized in Annex A.

Method 1: UE based measurement logging
In this method the UE logs events and measurements available at the UE, and these events/measurements are obtained by the network from the UE. The content of UE logs and some associated logging mechanisms are described in section 6.

Method 2: Existing RRM measurements and reporting
In this method the UE measurements are obtained through the existing RRM measurement and reporting mechanism [4][5]. In addition, other knowledge and information in the network regarding the UE from which measurements are obtained can be combined with the UE measurements to derive the occurrence of particular event.

Evaluations:
The evaluations have shown in [7] that existing periodical measurements could be utilized to a certain extent to detect coverage holes. However, in order to associate the periodical measurements with positioning information at eNBs (i.e. for LTE), the LTE RRC protocol would need to be modified to support transport of UE positioning information. For UMTS, the periodical measurements can be associated with positioning information which can be made available to the RNC if the RNC issues a MEASUREMENT CONTROL with 'measurement type' set to "UE positioning measurement".

Further more if accompanied by UE measurement "RLF report" (a new functionality, which may be already supported in Rel-9 for the SON mobility robustness optimization use case) additional information leading to less false alarms could be achieved as shown in simulations made in [6] even in interference scenarios. However, it was also concluded that RLF reporting alone cannot be used to provide DL pilot strength plots.

The evaluation in [9] concluded that in case of the UE measurement "Power headroom becomes less than threshold", it would be beneficial if Power Headroom reporting would be accompanied by additional measurement/information available at eNB/NodeB (e.g. UL grant information) and/or the UE (e.g. pathlosss), in order to increase the reliability of finding uplink coverage problems.

Comparison between Method 1 and Method 2:
The evaluation in the study also showed that in the existing RRM measurement reporting method the following information is missing:

- Reporting of accurate location information available in the UE;
- Problems found by IDLE mode UEs;
- Problems experienced when no RRC connection re-establishment is possible (i.e. going out-of-coverage);

It is understood that UE logging mechanism as described in section 6 should be able to provide solutions for above mentioned cases.

Further the following benefits of UE based logging were recognized in the study:

- UE based measurement logging will result in less signalling overhead than individual RRC measurement reporting, unless existing RRM measurement reporting for normal operations is sufficient.
- Obtaining a measurement from before a certain event takes place in a UE or at the time the event takes place [8] is difficult with the existing measurement reporting mechanism

The following benefits of utilizing the existing RRM measurement reporting (obtained through the normal operations without additional reporting) were further recognized in the study:

- As the RRM measurement (with positioning information only for UMTS) reporting is supported also by legacy UEs, measurement reporting from larger population of UE is obtainable also for the purposes of minimisation of drive test.

Impact analysis:
The study showed that UE/end user/network impacts are manageable by taking into account the guidances provided in section 7.

Annex A: Simulation results

A.1 Simulation [6]

In this simulation the possibility of utilizing UE reporting of radio environment measurements at Radio Link Failure event ("RLF report") for coverage hole detection was evaluated. It has been shown that the RLF report provides good performance in terms of coverage problem detection:

- Provides means for classification of RLF failures, which can also be used for mobility optimization
- High reliability (i.e. low false alarm rate) of separating coverage problems from other reasons for RLF, high success rate with very low "false alarm" rate
- Is not affected by interference scenarios, both in presence of uncoordinated interference as well as cell overlap due to bad network planning

Other points that can be concluded from the performance evaluations:

- RLF reporting is effective in providing information to identify the coverage issues with minimized UE involvement
- The RLF reporting is targeted particularly for coverage problem detection but may also be used for other use cases, e.g. mobility optimisation

A.2 Simulation [7]

In this simulation the possibilities for network based solutions of coverage and mobility optimization based on UE measurements before and after RLF was studied. The result showed that coverage hole and handover related radio link failures can be well distinguished based on terminal measurements recorded from the period immediately preceding the radio link failures, by detecting the following distinct events with the corresponding criteria.

- Handover failure: UE measures better cell than serving during a given period preceding RLF
- Coverage hole: UE does not measure better cells during a given period preceding RLF
- RLF within or between cells: Tracking of UEs source and target cell

A.3 Simulation [8]

The simulation showed an example of UE based log that can be obtained around an RLF event without utilizing existing RRM measurement reporting. The following observations on the UE based logging were made.

- Measurements during idle mode can be obtained
- Measurements preceding given UE internal events (e.g. RLF) can be obtained
- Measurements associated with given UE internal events can be obtained

A.4 Simulation [9]

In this simulation the reliability of "Power headroom become less than threshold" measurement log defined in section 6 has been evaluated. The following observations were made:

- The UE based logging as defined in section 6 does not provide sufficient information to solve UL coverage problems
- Power Headroom threshold without taking into account the resource allocation will result in unnecessary reporting

- RX power and SINR measurements performed at eNB provide essential information for UL optimization

Annex B: Change history

Change history							
Date	TSG #	TSG Doc.	CR	Rev	Subject/Comment	Old	New
27.03.09	RAN2 #65bis	R2-092702	-	-	TR 36.805 v0.1.0, skeleton TR as agreed by RAN2 #65		0.1.0
30.04.09	RAN2 #66	R2-093303	-	-	TR 36.805 v0.1.1 including agreements of R2-092703	0.1.0	0.1.1
04.05.09	RAN2 #66	R2-093429	-	-	TR 36.805 v0.2.0, as agreed by RAN2 #66	0.1.1	0.2.0
19.05.09	RAN2 #66	R2-093594	-	-	TR 36.805 v0.3.0 including agreements of R2-093593	0.2.0	0.3.0
19.05.09	RAN #44	RP-090476	-	-	Submitted to TSG-RAN for information	0.3.0	1.0.0
27.08.09	RAN2 #67	R2-095301	-	-	TR 36.805 v1.1.0 as agreed by RAN2 #66bis	1.0.0	1.1.0
28.08.09	RAN2#67	R2-095325	-	-	TR 36.805 v1.2.0 as agreed by RAN2 #67	1.1.0	1.2.0
12.11.09	RAN2#68	R2-097374	-	-	TR 36.805 v1.3.0 as agreed by RAN2 #68	1.2.0	1.3.0
13.11.09	RAN2#68	R2-097513	-	-	TR 36.805 v2.0.0 for RAN approval	1.3.0	2.0.0
2009-12	RP-46	RP-091412	-	-	TR 36.805 approved by RAN #46	2.0.0	9.0.0