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IoT Network
Performance Evaluation
White Paper

IoT Network Performance Evaluation

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Contents

Foreword

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Introduction

The present document is part of a Network and terminal capability and performance evaluation as identified below:

Network and terminal capability and performance evaluation**, "Network-Performance-Evaluation (NPE); "**

1. Scope

The present document describes a Network Performance Model that can be used for evaluation of NB-IoT network performance.

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.

[1] ITU-T E-Series Recommendations: Overall network operation, telephone service, service operation and human factors

[2] 3GPP TS 36.331: "Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Resource Control (RRC) protocol specification".

[3] 3GPP TS 36.214: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer - Measurements".

[4] GTI Guideline for device Certification V1.0.0

[5] 3GPP TS 36.413: "S1 Application Protocol (S1AP)".

[6] 3GPP TS 36.304: "Evolved Universal Terrestrial Radio Access (E-UTRA), User Equipment (UE) procedures in idle mode".

3. Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the terms and definitions given as follows:

Accuracy: A performance criterion that describes the degree of correctness with which a function is performed. (The function may or may not be performed with the desired speed.)

Availability: Availability of an item to be in a state to perform a required function at a given instant of time or at any instant of time within a given time interval, assuming that the external resources, if required, are provided.

Network Measurement: Network measurement is a process to measure network.

Reliability:

1) Probability that a product or system will perform as required for a specified period of time.

2) The ability of an item to perform a required function under given conditions for a given time period.

Security:

1) 'Security' is the protection of information availability, integrity and confidentiality.

2) The term 'security' is used in the sense of minimizing the vulnerabilities of assets and resources. An asset is anything of value. Vulnerability is any weakness that could be exploited to violate a system or the information it contains. A threat is a potential violation of security.

3) The ability to prevent fraud as well as the protection of information availability, integrity and confidentiality.

Telecommunications Systems: The technical equipment or systems capable of sending, transmitting, switching, receiving, steering or controlling as messages identifiable electromagnetic signals.

User: An individual or organization using or requesting publicly available telecommunications services.

3.2 Abbreviations

For the purposes of the present document, the abbreviations given in TR 21.905 [4] 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 [4].

DT	The Drive Test
EM	Element Manager
eNB	E-UTRAN NodeB
EPC	Evolved Packet Core
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
KPI	Key Performance Indicator
KQI	Key Quality Indicator
MME	Mobility Management Entity
NE	Network Element
NI	Network Interface
NMS	Network Management System
NP	Network Performance
NM	Network Manager
OAM	Operation Administration Maintenance
RS	Reference Signal
RSRP	Reference Signal Received Power
SINR	Signal to Interference plus Noise Ratio
TB	Transport Block

UE	User Equipment

4. Concepts and background

4.1 Overview

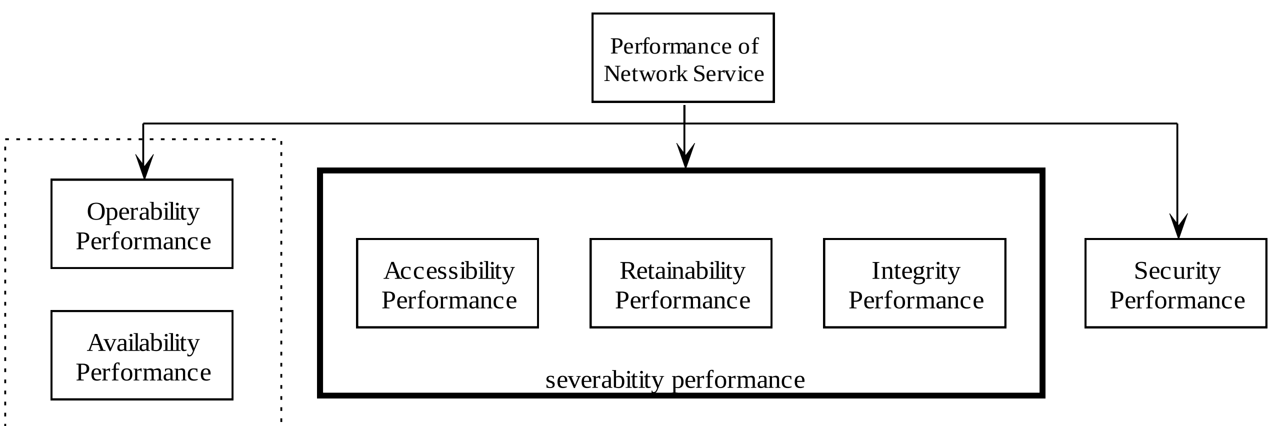
4.1.1 General description

In order to evaluate the condition of the NB-IoT network, Figure4-1 (Performance of Network Service) is a framework intended to provide a general guide to the factors which contribute collectively to the overall network performance of service as perceived by the user of a telecommunication service. The terms in the diagram can be thought of as generally applying either to the network performance levels actually achieved in practice, to objectives which represent network performance goals, or to requirements which reflect design specifications.

It is obvious that a service can be used only if it is provided, and it is desirable that the provider has a detailed knowledge about the quality of the offered service. From the provider's viewpoint, network performance is a concept by which network characteristics can be defined, measured and controlled to achieve a satisfactory level of service quality.

It is up to the Service Provider to combine different network performance parameters in such a way that the economic requirements of the Service Provider as well as the satisfaction of the User are both fulfilled.

Figure4-1 Performance of Network Service



4.1.2 General performance concepts

All performance concepts may be related to instant of time (instantaneous, etc.) or expressed as a mean value over a time interval.

The User's degree of satisfaction with the service provided depends on quality of service that is on the following performance:

- the availability performance;
- the operability performance;
- the severability performance;
- the security performance.

Among which serveability performance describes the ability of a service to be obtained within specific tolerances and other given conditions, when requested by a user, and to continue being provided for the request duration. It is further subdivided into three terms:

- accessibility performance;
- retainability performance;
- integrity performance.

Therefore, from the perspective of telecom service end users, serveablity performance is thought as most relevant to their requirements about the network. Also it is mostly affected by various factors and will be highlighted in this paper.

The properties expressed by these measures impact the measures relating to quality of service and network performance and are thus implicitly characterizations of these performance measures. Measures are connected to events (failure, restoration, etc.), states (fault, up state, down state, outage, etc.) or activities (e.g. maintenance), with their time durations.

The ability of a network or network portion to provide the functions related to communications between users.

1 Network performance applies to the Network Provider's planning, development, operations and maintenance is the detailed technical part of KQI.

2 Network performance is the main influence on severability performance.

3 Network performance measures are meaningful to network providers and are quantifiable at the part of the network to which they apply.

4 It is up to the Network Provider to combine the Network Performance parameters in such a way that the economic requirements of the Network Provider, as well as the satisfaction of the User, are both fulfilled.

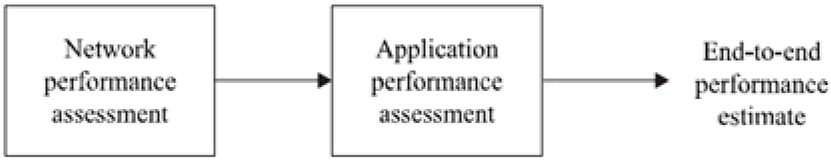
4.2 End-to-end performance estimation

This Recommendation covers the process of estimating end-to-end performance of applications operating on NB-IoT networks, using:

* performance of the NB-IoT network, based on relevant measurements or network modelling results;
* specifications of the application of NB-IoT, a model of the application using network performance and customer appliance performance as input and producing a key metric of application performance as a result;
* a perceptual model intended for the applications of NB-IoT, to interpret the application performance as an estimate of the quality experienced by a typical population of users.

Figure 4-2 illustrates the general process used to develop an end-to-end performance estimate .

Figure 4-2 Process to obtain end-to-end performance estimate



The steps to obtain network and application performance may be combined in some cases, such as when a simulation provides a means to measure the performance of a particular session, or set of sessions.

4.2.1 Network performance assessment

Network performance may be assessed in terms of test or KQI monitor. Network measurements allow the assessor to treat the network as a black-box, there are several important considerations for the measurement design, including:

1) Probe of network, including signalling trace, measurement counters, etc.

2) Drive Test (DT)

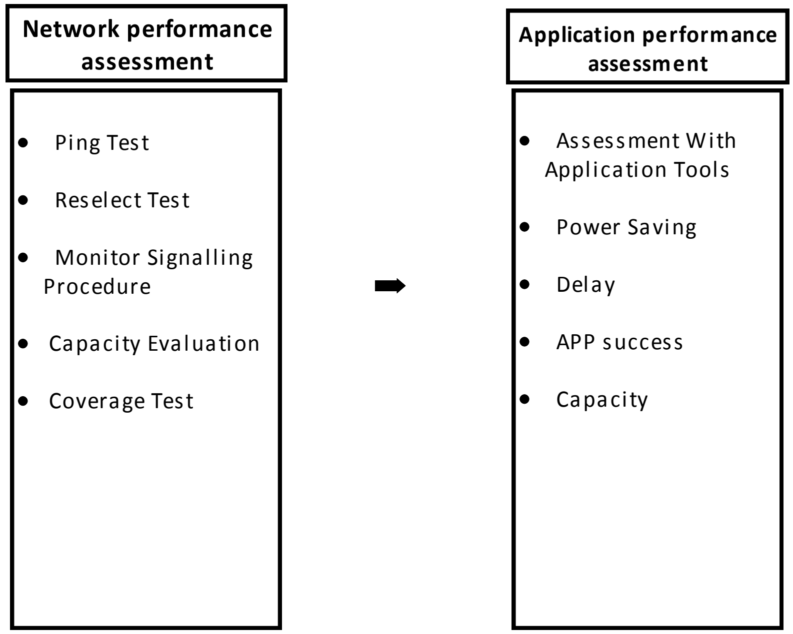
4.2.2 Application performance assessment

Application models take the estimates of network performance and information describing application device performance as inputs, and produce one or more key metrics of application performance as outputs.

4.2.3 Framework for models in the end-to-end performance assessment process

Figure 4-3 illustrates the various alternatives in the process to estimate the end-to-end performance of applications on NB-IoT networks. As indicated in this figure, there are many options available to complete the process, although in practice the assessor must combine options that are consistent with the goal of an end-to-end estimate.

Figure 4-3 Framework for developing end-to-end NB-IoT performance estimate



4.3 NB-IoT network performance monitoring point

4.3.1 NB-IoT network structure

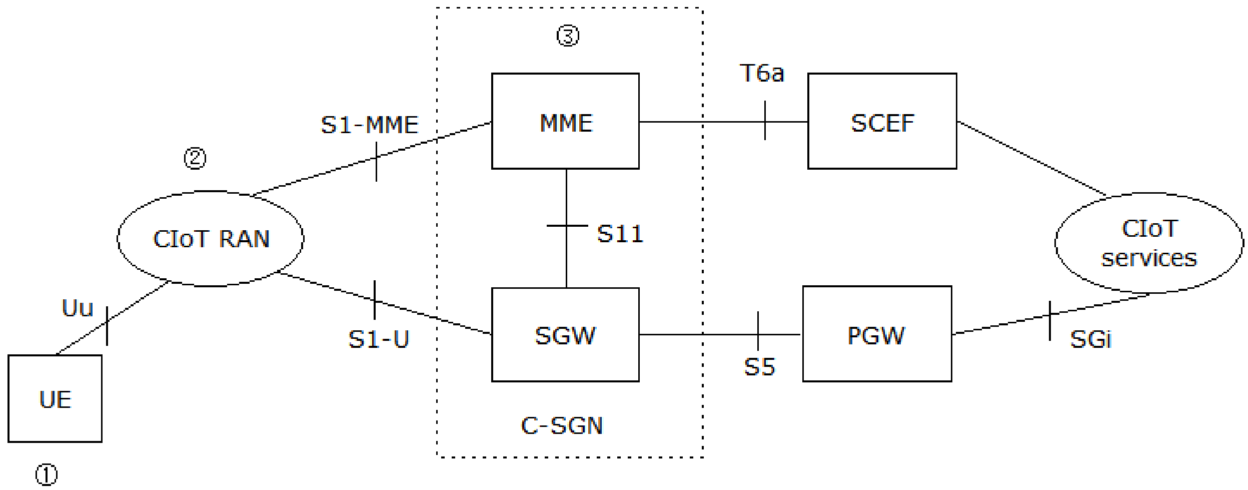
The NB-IoT network structure is basically the same as LTE, but as for the NB-IoT optimization procedure, the structure has been enhanced accordingly. On the Control Plane CloT EPS optimization, UL data are transferred from eNB(CIoT RAN) to MME. From MME, UL data may either be transferred via Serving Gateway(SGW) to Packet Data Network Gateway(PGW), or to Service Capability Exposure Function(SCEF) which however is only possible for non-IP data packets. From these nodes, they are finally forwarded to the application server (CIoT services). DL data is transmitted over the same paths in the reverse direction. In this solution, there is no data radio bearer set up, data packets are sent on signalling radio bearer instead. Consequently, this solution is most appropriate for the transmission of infrequent and small data packets.

The SCEF is a new node designed especially for machine type data. It is used for delivery of non-IP data over control plane and provides an abstract interface for the network services (authentication and authorization, discovery and access network capabilities).

With the User Plane CIoT EPS optimization, data is transferred in the same way as the conventional data traffic, i.e. over radio bearers via the SGW and the PGW to the application server. Thus it creates some overhead on building up the connection. However it facilitates a sequence of data packets to be sent. This path supports both IP and non-IP data delivery.

Figure 4-4 Network structure for the NB-IoT data transmission and reception. The network performance monitoring point is also indicated with numbered symbol.

Figure 4-4 Network structure for the NB-IoT



4.3.2 NB-IoT network performance monitoring point

4.3.2.1 Monitoring point 1 — PT1

This point is located at UE or at the co-located measurement equipment. There are two options to execute the drive test measurements:

1. If NB-IoT UEs should be used, the UE may perform a cell reselection procedure according to cell reselection rule (chapter 5.4). This additional procedure takes some time so that the measurement resolution during a drive test seems questionable in particular for the RF coverage measurements (RSRP, SINR). But for mobility application scenarios, such as smart electric bicycle, it is useful and necessary to perform such test to assess the real network performance.
2. The classical method for the pure Rx measurements like RSRP and SINR (chapters 5.1. and 5.2.) is using a network scanner. A network scanner is measuring all cells / PCIs that could be received at the certain location. In fact, this is the only chance to verify the NB-IoT network planning to measure not only the best cell but also the neighboring cells including the RSRP differences. A network scanner can do several RSRP and SINR measurements per second, which provides a superior measurement resolution. In addition, it can measure the LTE signals in parallel, which gives good insights in why a network performance (e.g. SINR) is maybe not as good as expected. Therefore, a network scanner is well suited (and developed) for drive tests.

With CQT or DT (Drive Test), the following information can be captured from PT1:

Use Case Stage	Description
RSRP Distribution Percentage - DT	This KQI indicates the coverage level of the network. According to different coverage scenarios, the evaluated standard should be different.
SINR Distribution Percentage - DT	This KQI indicates the interference level of the network.
Attach Success Rate - DT	This KQI indicates success rate of UE initiated EPS attach request
Cell Reselection Success Rate - DT	This KQI indicates success rate of UE initiated cell reselection after the cell reselection rules satisfied
Ping Success Rate - DT	This KQI indicates success rate of Ping test

4.3.2.2 Monitoring point 2 — PT2

This point is located at eNB. eNB reports the counters to NMS for visualized query. The following information can be captured from PT2:

Use Case Stage	Description
RRC Connection Establishment Success Rate – eNB	This KQI indicates the success rate of RRC connection establishment.
RRC Drop Rate – eNB	This KQI indicates the rate of abnormal RRC connection release.
Maximum Number of RRC Connections	This KQI indicates the RRC connections
Cell Uplink/Downlink BLER - eNB	This KQI indicates the uplink/downlink block error rate at the air interface

4.3.2.3 Monitoring point 3 — PT3

This point is located at MME. Paging procedure is transparent for eNB and initiated by MME, it is better to monitor Paging Success Rate from PT3.

Use Case Stage	Description
Paging Success Rate – MME	This KQI indicates the success rate of paging

5. Definitions of NB-IoT KQI

5.1 RSRP Distribution Percentage - DT

- Definition

  Reference signal received power (RSRP), is defined as the linear average over the power contributions (in [W]) of the resource elements that carry cell-specific reference signals within the considered measurement frequency bandwidth.

  It is an important indicator to evaluate the coverage of a network. Poor coverage can cause abnormal interrupt of service, high packet loss rate or long delay time, thus good RSRP value is always pursued. A simultaneous RSRP and SINR measurement in LTE is beneficial to understand and interpret NB-IoT measurement results.

- Formula

  The evaluated RSRP threshold should be different according to different coverage scenarios:

  - Outdoor Coverage: during drive test, when signal > -110dbm, that means the signal is strong enough for outdoor coverage.
    The formula is: Samples of RSRP > -110dbm / Total Valid Samples
  - Indoor Coverage: during drive test, when signal > -90dbm, that means the signal is strong enough for indoor coverage.
    The formula is: Samples of RSRP > -90dbm / Total Valid Samples
  - Deep Indoor Coverage: during drive test, when signal > -80dbm, that means the signal is strong enough for deep indoor coverage.
    The formula is: Samples of RSRP > -80dbm / Total Valid Samples

- Priority

  Mandatory

5.2 SINR Distribution Percentage -DT

- Definition

  Reference signal-signal to noise and interference ratio (RS-SINR), is defined as the linear average over the power contribution (in [W]) of the resource elements carrying cell-specific reference signals divided by the linear average of the noise and interference power contribution (in [W]) over the resource elements carrying cell-specific reference signals within the same frequency bandwidth.

  The higher the value is, the better the radio environment will be. With good SINR, the network accessibility and retainability can be guaranteed. . A simultaneous RSRP and

SINR measurement in LTE is beneficial to understand and interpret NB-IoT measurement results.

- Formula

The downlink interference can be defined as four grades according to the range of SINR value:

Excellent Point: SINR > 22dB
Good Point: 15dB < SINR < 22dB
Normal Point: 5dB < SINR<10dB
Weak Point: SINR < 0dB

- Priority

Mandatory

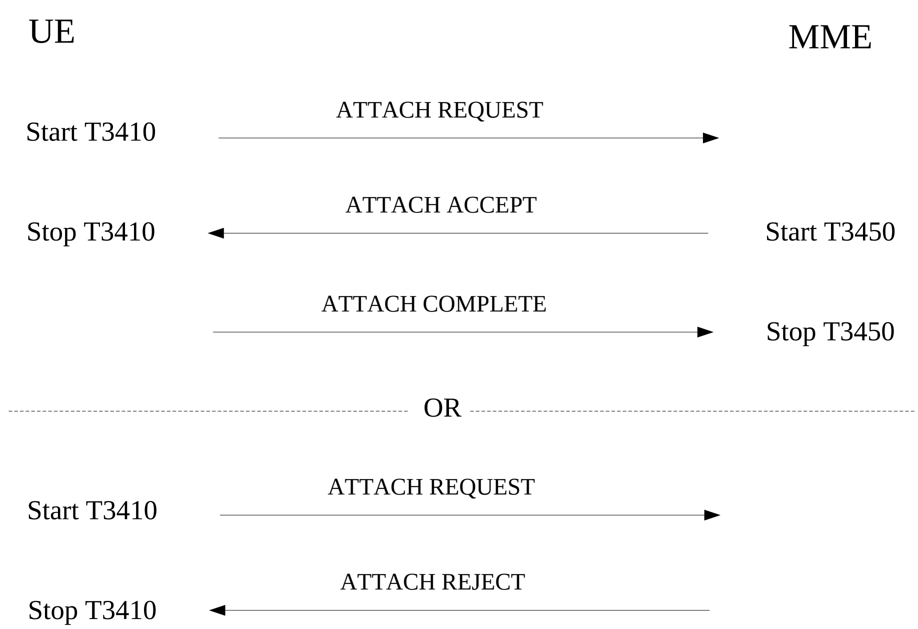
5.3 Attach Success Rate - DT

- Definition

The attach procedure is used to attach to an EPC for packet services in EPS. With a successful attach procedure in NB-S1 mode, a context is established for the UE in the MME. If the attach request included information to request PDN connectivity, a default bearer is also established between the UE and the PDN.

After a successful attach procedure, UE can process data transmission with PGW.

Figure 5-1 Normal and abnormal attach Procedure



- Formula

Number of Attach Complete Times / Number of Attach Attempts

- Priority

  Mandatory

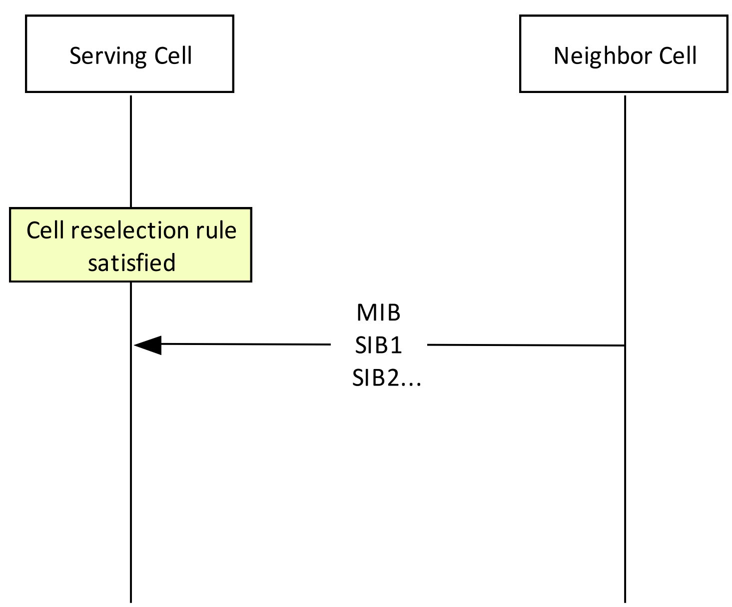
5.4 Cell Reselection Success Rate - DT

- Definition

  For NB-IoT, there is no handover procedure involved. UE can only perform cell reselection during idle mode. In order for continuous service, cell reselection is very important for mobility scenarios. The cell reselection rule is specified in 3GPP TS 36.304.

  When the requirements for cell reselection are satisfied, UE should perform cell reselection procedure and try to decode system information of the neighbor cell. If UE successfully decodes system information and camp on the neighbor cell, it should be counted as a successful cell reselection event.

Figure 5-2 Cell Reselection Procedure



- Formula

  Number of Cell Reselection Success Times / Number of Cell Reselection Attempts

- Priority

  Optional

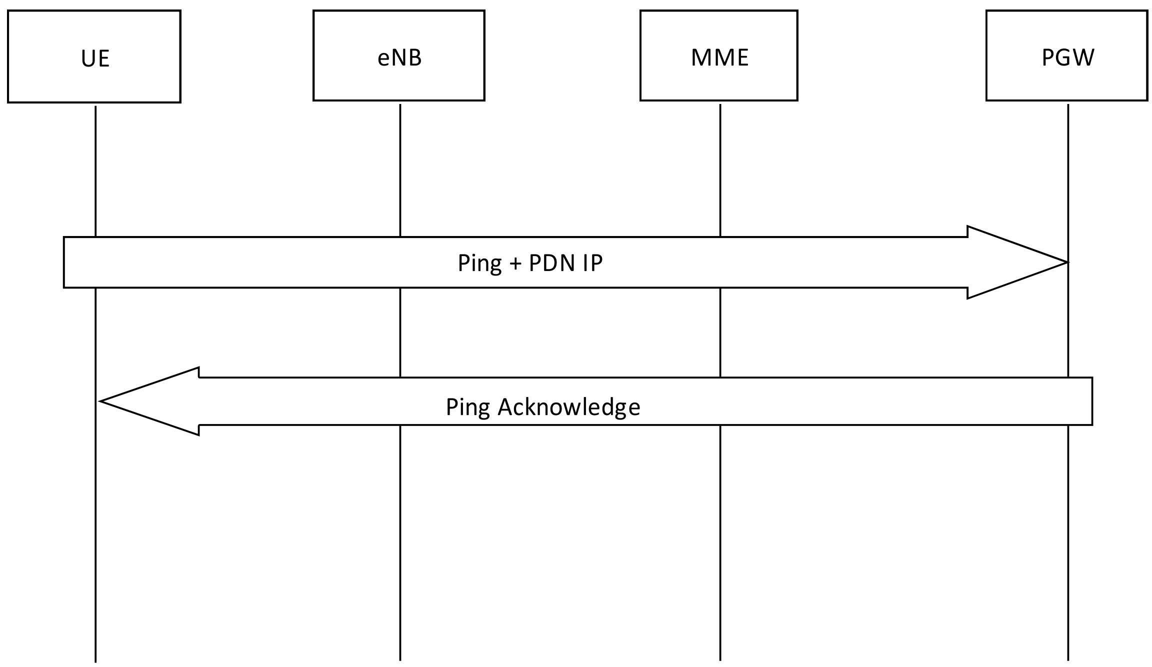
5.5 Ping Success Rate - DT

- Definition

  For NB-IoT, the most common application is small data transfer. Ping Success Rate can indicate the overall performance of the network. There are many factors that may influence this KQI, such as the resource scheduling algorithm of eNB, the network reliability, radio environment and configuration of radio parameters, etc. To assess the network performance correctly during a drive test, the Ping Success Rate tests always have to be executed in the best-received cell (best server).

  Lower packet loss rate can be considered as a good network, otherwise the network need to be optimized.

Figure 5-3 Ping Procedure Schematic Diagram



- Formula

  Number of Ping Success Times / Number of Ping Attempts

- Priority

  Optional

5.6 RRC Connection Establishment Success Rate - eNB

- Definition

  UE may initiate RRC Connection Request due to the following reasons:

1) Mobile Terminating Access

2) Mobile Originating Data

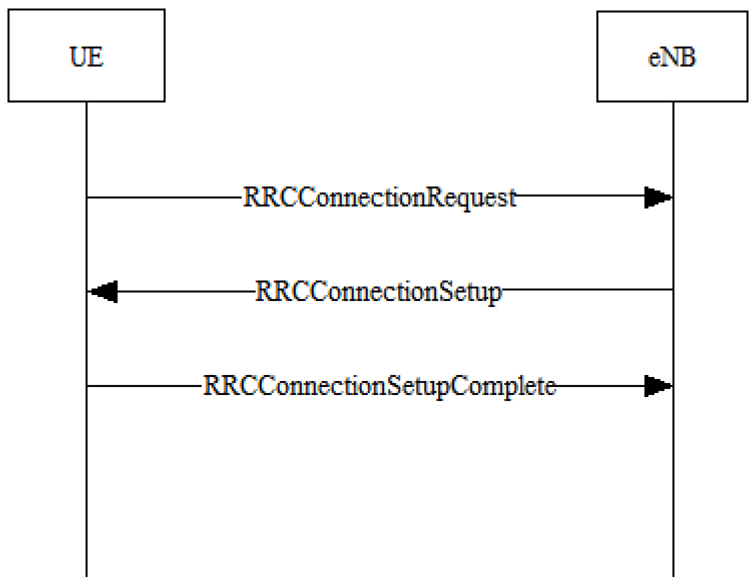
3) Mobile Originating signalling

4) Mobile Originating Exception Data

5) Delay Tolerant Access

RRC connection establishment success rate evaluates the air interface signalling establishment performance between UE and eNB. Figure 4-7 indicates the successful RRC connection setup procedure:

Figure 5-4 RRC connection setup procedure



- Formula

  Number of RRC Connection Setup Complete Times / Number of RRC Connection Request Times

- Priority

  Mandatory

5.7 RRC Drop Rate - eNB

- Definition

  Abnormal release of RRC connection during RRC-CONNECTED mode will terminate the on-going service, and this KQI indicates the retainability performance of the network. RRC connection release procedure can be triggered by MME or eNB as described in the following charts:

Figure 5-5a RRC Connection Release Procedure triggered by eNB

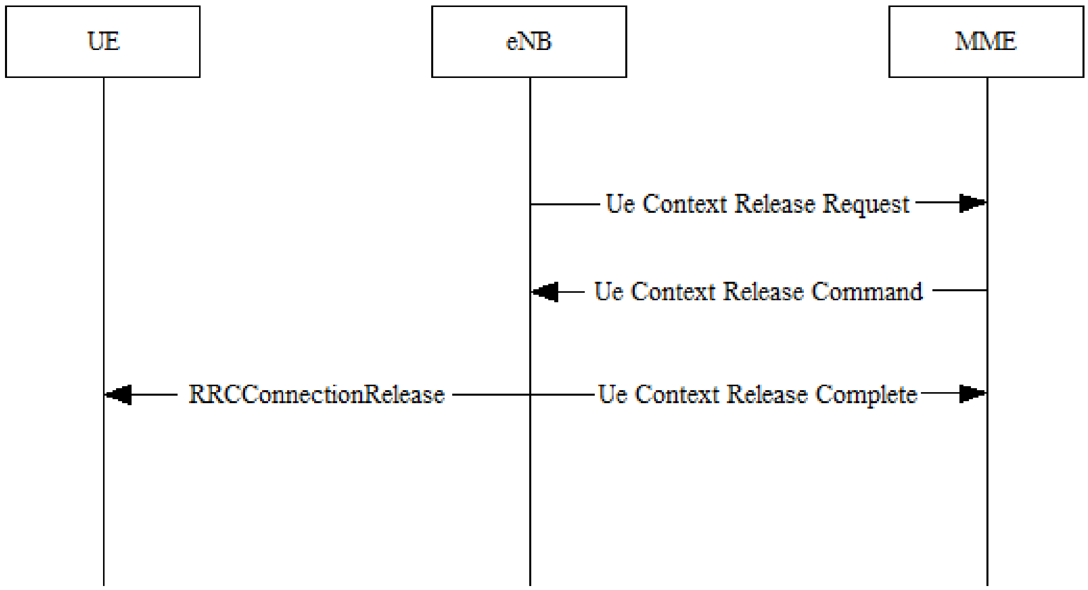
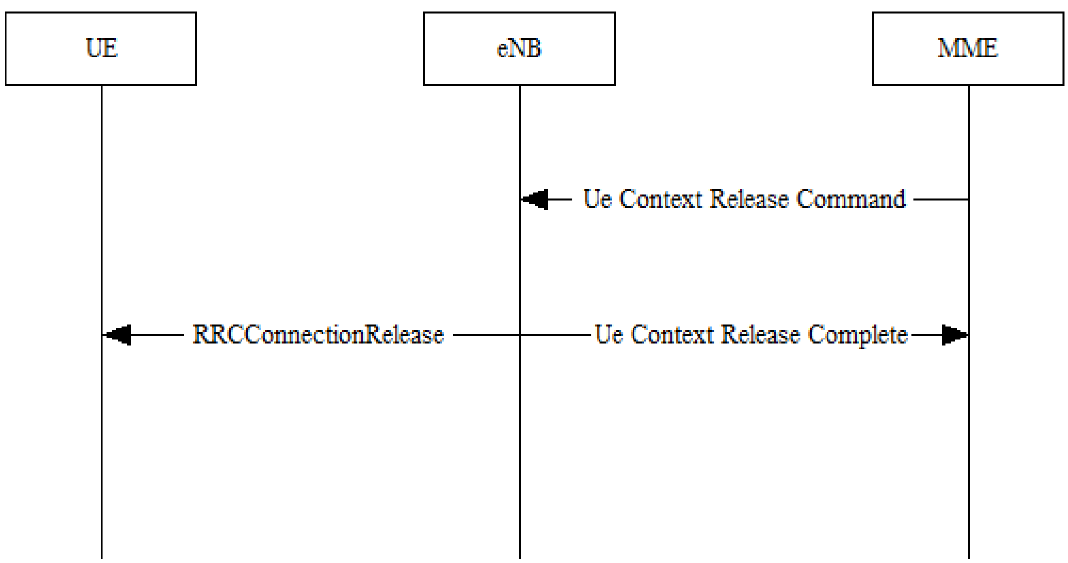


Figure 5-5b RRC Connection Release Procedure Triggered by MME



The causes contained in Ue Context Release Request/Command message can be referred to 3GPP TS 36.413 9.2.1.3 as shown in the tables below .Since the causes provided in 3GPP applied for both LTE and NB-IoT technology, for NB-IoT, the causes will be trimmed, among which the abnormal causes will be considered as RRC drop.

Radio Network Layer cause	Meaning
Unspecified	Sent for radio network layer cause when none of the specified cause values applies.
TX2RELOCOverall Expiry	The timer guarding the handover that takes place over X2 has abnormally expired.
Successful Handover	Successful handover.
Release due to E-UTRAN generated reason	Release is initiated due to E-UTRAN generated reason.
Handover Cancelled	The reason for the action is cancellation of Handover.
Partial Handover	Provides a reason for the handover cancellation. The HANDOVER COMMAND message from MME contained *E-RABs to Release List* IE and the source eNB estimated service continuity for the UE would be better by not proceeding with handover towards this particular target eNB.
Handover Failure In Target EPC/eNB Or Target System	The handover failed due to a failure in target EPC/eNB or target system.
Handover Target not allowed	Handover to the indicated target cell is not allowed for the UE in question.
$TS1_{RELOCoverall}$ Expiry	The reason for the action is expiry of timer $TS1_{RELOCoverall}$.
$TS1_{RELOCprep}$ Expiry	Handover Preparation procedure is cancelled when timer $TS1_{RELOCprep}$ expires.
Cell not available	The concerned cell is not available.
Unknown Target ID	Handover rejected because the target ID is not known to the EPC.
No radio resources available in target cell	Load on target cell is too high.
Unknown or already allocated MME UE S1AP ID	The action failed because the MME UE S1AP ID is either unknown, or (for a first message received at the eNB) is known and already allocated to an existing context.
Unknown or already allocated eNB UE S1AP ID	The action failed because the eNB UE S1AP ID is either unknown, or (for a first message received at the MME) is known and already allocated to an existing context.
Unknown or inconsistent pair of UE S1AP ID	The action failed because both UE S1AP IDs are unknown, or are known but do not define a single UE context.
Handover Desirable for Radio Reasons	The reason for requesting handover is radio related.
Time Critical Handover	Handover is requested for time critical reason i.e., this cause value is reserved to represent all critical cases where the connection is likely to be dropped if handover is not performed.
Resource Optimisation Handover	The reason for requesting handover is to improve the load distribution with the neighbour cells.
Reduce Load in Serving Cell	Load on serving cell needs to be reduced. When applied to handover preparation, it indicates the handover is triggered due to load balancing.

User Inactivity	The action is requested due to user inactivity on all E-RABs, e.g., S1 is requested to be released in order to optimise the radio resources.
Radio Connection With UE Lost	The action is requested due to losing the radio connection to the UE.
Load Balancing TAU Required	The action is requested for all load balancing and offload cases in the MME.
CS Fallback triggered	The action is due to a CS fallback that has been triggered. When it is included in UE CONTEXT RELEASE REQUEST message, it indicates the PS service suspension is not required in the EPC.
UE Not Available for PS Service	The action is requested due to a CS fallback to GERAN that has been triggered. When it is included in the UE CONTEXT RELEASE REQUEST message, it indicates that the PS service suspension is required in the EPC due to the target GERAN cell or the UE has no DTM capability.
Radio resources not available	No requested radio resources are available.
Invalid QoS combination	The action was failed because of invalid QoS combination.
Inter-RAT Redirection	The release is requested due to inter-RAT redirection or intra-LTE redirection. When it is included in UE CONTEXT RELEASE REQUEST message, the behaviour of the EPC is specified in TS 23.401 [11].
Failure in the Radio Interface Procedure	Radio interface procedure has failed.
Interaction with other procedure	The action is due to an ongoing interaction with another procedure.
Unknown E-RAB ID	The action failed because the E-RAB ID is unknown in the eNB.
Multiple E-RAB ID Instances	The action failed because multiple instance of the same E-RAB had been provided to the eNB.
Encryption and/or integrity protection algorithms not supported	The eNB is unable to support any of the encryption and/or integrity protection algorithms supported by the UE.
S1 Intra system Handover triggered	The action is due to a S1 intra system handover that has been triggered.
S1 Inter system Handover triggered	The action is due to a S1 inter system handover that has been triggered.
X2 Handover triggered	The action is due to an X2 handover that has been triggered.
Redirection towards 1xRTT	The release of the UE-associated logical S1 connection is requested due to redirection towards a 1xRTT system e.g., CS fallback to 1xRTT, or SRVCC to 1xRTT, when the PS service suspension is required in the EPC. During this procedure, the radio interface message might but need not include redirection information.
Not supported QCI Value	The E-RAB setup failed because the requested QCI is not supported.
Invalid CSG Id	The CSG ID provided to the target eNB was found invalid.
Release due to Pre-Emption	Release is initiated due to pre-emption.

Transport Layer cause	Meaning
Transport Resource Unavailable	The required transport resources are not available.
Unspecified	Sent when none of the above cause values applies but still the cause is Transport Network Layer related.

Protocol cause	Meaning
Transfer Syntax Error	The received message included a transfer syntax error.
Abstract Syntax Error (Reject)	The received message included an abstract syntax error and the concerning criticality indicated “reject”.
Abstract Syntax Error (Ignore And Notify)	The received message included an abstract syntax error and the concerning criticality indicated “ignore and notify”.
Message Not Compatible With Receiver State	The received message was not compatible with the receiver state.
Semantic Error	The received message included a semantic error.
Abstract Syntax Error (Falsely Constructed Message)	The received message contained IEs or IE groups in wrong order or with too many occurrences.
Unspecified	Sent when none of the above cause values applies but still the cause is Protocol related.

Miscellaneous cause	Meaning
Control Processing Overload	Control processing overload.
Not Enough User Plane Processing Resources Available	No enough resources are available related to user plane processing.
Hardware Failure	Action related to hardware failure.
O&M Intervention	The action is due to O&M intervention.
Unspecified Failure	Sent when none of the above cause values applies and the cause is not related to any of the categories Radio Network Layer, Transport Network Layer, NAS or Protocol.
Unknown PLMN	The MME does not identify any PLMN provided by the eNB.

The abnormal release of RRC connection can be due to:

1) Unavailable resource , according to Radio Network Layer cause: Radio resources not available
2) S1 Link Failure, according to Transport Layer cause:Transport Resource Unavailable
3) eNB radio link failure, according to Radio Network Layer cause: Failure in the Radio Interface Procedure
4) Shut down or reset of the cell, according to Radio Network Layer cause: Cell not available, Miscellaneous cause: O&M Intervention
5) Other causes: none of the above abnormal causes

- Formula

Number of RRC connections released abnormally / Number of RRC connections established successfully

- Priority

Mandatory

5.8 Cell Uplink/Downlink BLER - eNB

- Definition

  Cell Uplink BLER: This indicator indicates the uplink block error rate at the air interface, meaning that the ratio of the number of uplink TB blocks obtaining NACK responses to the total number of scheduled uplink TB blocks. It is used to describe the radio environmental quality of the air interface.

  Cell Downlink BLER: This indicator indicates the downlink block error rate at the air interface, meaning that the ratio of the number of downlink TB blocks obtaining NACK responses to the total number of downlink sent TB blocks. It is used to describe the radio environmental quality of the air interface and provides a basis for network optimization.

- Formula

  Error Number of UL TBs / Total Number of UL TBs
  Error Number of DL TBs / Total Number of DL TBs

- Priority

  Optional

5.9 Maximum Number of RRC Connections - eNB

- Definition

  The maximum number of RRC connections can indicate the busyness of a NB-IoT cell. If a lot of users access to the cell simultaneously, the RRC connections may exceed the limit of the system which will cause deterioration of network performance. The network provider can use this indicator to decide whether to expand the capacity of the network.

  The number of RRC connections is sampled at a short time interval, and the maximum value within a statistical period will be reported.

- Formula

  Maximum Number of RRC Connections per time granularity

- Priority

  Optional

5.10 Paging Success Rate - MME

- Definition

  The paging procedure is used by the network to request the establishment or resumption of a NAS signalling connection to the UE. Another purpose of the paging procedure is to prompt the UE to reattach if necessary as a result of a network failure.

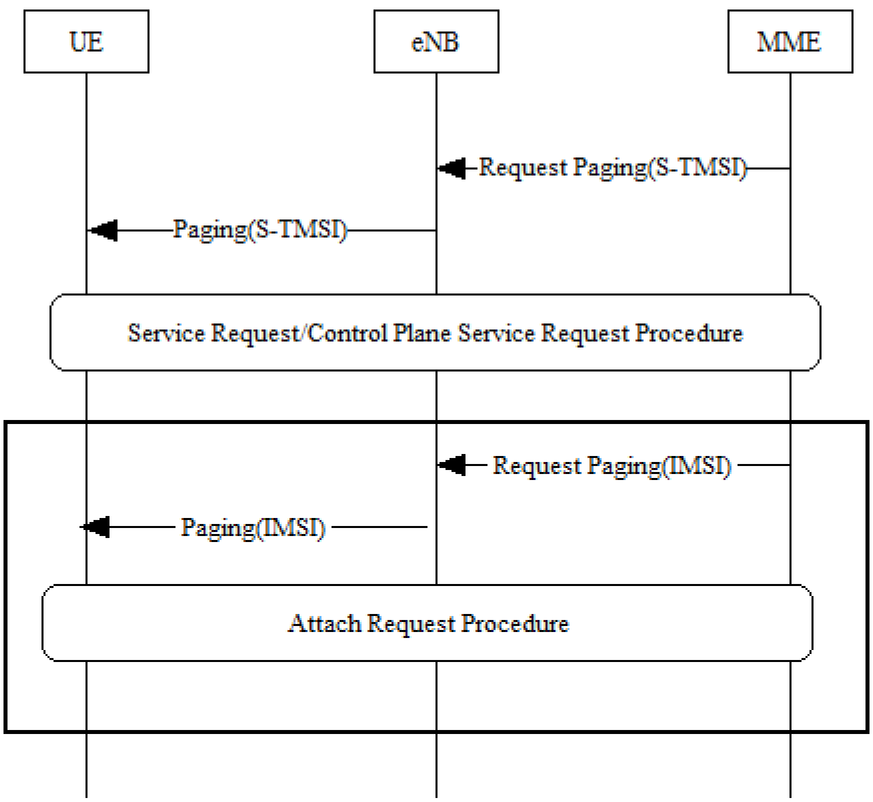
If the UE is not attached when it receives a paging for EPS services, the UE shall ignore the paging.

MME may initiate paging procedure using S-TMSI When NAS signalling messages or user data is pending to be sent to the UE when no NAS signalling connection exists. MME may initiate paging using IMSI if the S-TMSI is not available due to a network failure.

Paging success rate is an important KQI to evaluate the quality of the network. With successful paging procedure, NAS signalling messages or user data can be delivered afterwards, otherwise the service will be considered as failure.

Normally MME may initiate more than one paging attempts in order to enhance the paging success rate.

Figure 5-6 Paging procedure with S-TMSI or IMSI



- Formula

Number of Paging Success Times / Number of Paging Attempts

- Priority

Optional

6. NB-IoT Network Performance Evaluation Model

6.1 Model of Network performance evaluation

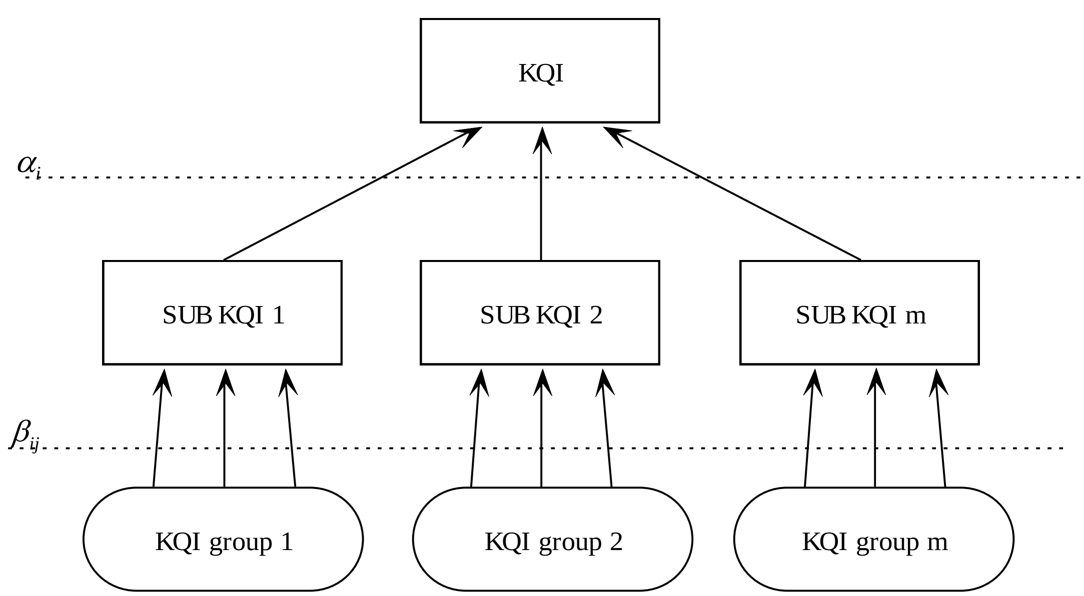
The network performance is divided into the overall perception and sub-sense, sub-item awareness is the index system corresponding to the indicators; the overall perception is the user The comprehensive perceived situation of the evaluated business is a comprehensive reflection of the sensitivities of all sub-items corresponding to the business.

The overall sensitivity is linearly weighted by the sub-item perception, and the corresponding weight coefficient matrix is α , obtained by analyzing and processing the user's survey data. α Reflecting the user expectations, the service provider's brand, customer service and price factors such as the impact of user perception.

The sub-item awareness is linearly weighted by the corresponding KQI index, and the corresponding weight coefficient matrix is β , which reflects the different degree of influence of different KQI indicators on user perception.

Network objective performance factors other than the basic stability of the case, the weight coefficient α and β also correspondingly unchanged.

Figure 6-1 network performance evaluation structure model



6.2 Mathematical description of the model

From the model variable structure relationship, we can get the following mathematical model:

$$\begin{cases} \eta = \alpha \bullet Y^T \\ Y = \beta \bullet X^T \end{cases}$$

among, η indicating the overall network performance perception;

$Y = (y_1, y_2, \cdots, y_m)$, y_i Indicates sub-item awareness,, $i = 1, 2, \cdots, m$;

$\alpha = (\alpha_1, \alpha_2, \cdots, \alpha_m)$, α_i Represents the weight coefficient of the sub-item y_i, and $\alpha_1 + \alpha_2 + \cdots + \alpha_m = 1$;

$X = (x_1, x_2, \cdots, x_n)$, x_j Represents the percentile value of the KQI indicator, $j = 1, 2, \cdots, n$;

$$\beta = \begin{pmatrix} \beta_{11}, \beta_{12}, \cdots, \beta_{1n} \\ \beta_{21}, \beta_{22}, \cdots, \beta_{2n} \\ \vdots \\ \beta_{m1}, \beta_{m2}, \cdots, \beta_{mn} \end{pmatrix}$$

, β_{ij} the sub-item awareness y_i is linearly represented by the corresponding KQI,, x_j Weight coefficient of KPI index. If a sub-item awareness is only for a KPI, then, weighting factor β_{ij} is 1。

For example：

$y_i = \beta_i X^T$, that means

$$y_i = (\beta_{i1}, \beta_{i2}, \cdots, \beta_{in}) \begin{pmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{pmatrix}$$

6.3 NB-IoT Network Performance Evaluation

SUB KQI	α	KQI category	KQI item	β	Formula (Fn)
Y1 accessibility performance	α_1	X11	Attach Success Rate - DT	β_{11}	F11
		X12	RRC Connection Establishment Success Rate - eNB	β_{12}	F12
		X13	Paging Success Rate – MME	β_{13}	F13
Y2 retainability performance	α_2	X21	Cell Reselection Success Rate – DT	β_{21}	F21
		X22	RRC Drop Rate – eNB	β_{22}	F22
		X33	Maximum Number of RRC Connections	β_{23}	F23
Y3 Integrity performance	α_3	X31	Ping Success Rate – DT	β_{31}	F31
		X32	Cell Uplink/Downlink BLER – eNB	β_{32}	F32
Y4 Coverage	α_4	X41	RSRP Distribution Percentage - DT	β_{41}	F41
		X42	SINR Distribution Percentage - DT	β_{42}	F42

α_i Represents the weight coefficient of the sub-item

β_{ij} Represents the weight coefficient of the sub-item Xi

x_j Represents the percentile value of the KQI indicator，

y_i Indicates sub-item awareness

Fn：Formula to calculate the scores, can be defined by

The value of these factors can be defined by network operators or the evaluation organization.

For example: Fn of Attach Success Rate – DT can be defined as X11=0,if attach success rate<90%=0 and X11=(attach success rate-90%)*100

7. NB-IoT network KQI for Application

NB-IoT can be deployed in wide range of fields such as public utilities, smart city and industries including smart metering, smart parking and intelligent security etc. This chapter illustrates the NB-IoT network KQI for practical application. The potential industries where NB-IoT technology can be applied to are listed as below, such as:

- Connected Vehicle
- Connected Urban Transport
- Smart Meters
- Smart Factory
- Smart Travel
- Smart Lighting
- Smart Parking
- Smart Service Vehicle
- Connected Cow

7.1 Scenario Characteristics

Parts of NB-IoT’s performance is related on the type of coverage, it is need to evaluate the three kind of coverage to do so. Usually UE will be in three coverage level cell level 0, cell level 1 and 2. Sample distribution will help to evaluation the network performance.

- 50%~80% samples shall be collected in Outdoor Coverage
- 10%~40% samples shall be collected in Indoor Coverage
- 10%~20% samples shall be collected in Deep Indoor Coverage

7.2 Evaluation of Application

7.2.1 Power consuming

There are many factor that affects the consuming of Power, according to the Certification Result of GTI, we can know the power saving ability of module. The packet size, reporting interval and coupling loss also influence the power consuming of the module.

In the same network, the reporting mode determines the consuming of power.

7.2.2 Service Delay

The service delay for NB-IoT is composed of time consumed within NB-IoT network and the delay between NB-IoT network and IoT application server, which is a service platform used to collect data.

Different coverage level will involve different time cost between UE and eNB. As is known, for NB-IoT, the coverage level can be divided into three classes: CEL 0,1,2 according to different RSRP received by UE. For CEL 0, the time cost is less as the repetition times for PUSCH or PDSCH transmission is less and MCS is higher compared to CEL1,2, thus more bytes can be carried for a certain time period.

The procedure and interactive times between UE and application server may be different for different service purposes which will cause different service delay.

- Type 1: UE Autonomous Reporting Data Exception Reports

Many sensor type applications are expected to monitor a physical condition and trigger an exception report when an event is detected. Such events are expected to be generally rare, typically occurring every few months or even years. Examples of such applications include smoke alarm detectors, power failure notifications from smart meters, tamper notifications etc.

- Type 2: UE Autonomous Reporting Periodic Data to Application Server

Periodic uplink reporting is expected to be common for cellular IoT applications such as smart utility (gas/water/electric) metering reports, smart agriculture, smart environment etc.

- Type 3: Network Command

The Network Command (NC) traffic model is used to model applications where an application server generates an application layer command to the device to perform an action without the need for an uplink response from the device e.g. command to switch on the lights or to trigger the device to send an uplink report as a result of the network command e.g. request for a smart meter reading.

The service delay is defined as the time consumed for one successful service procedure. The time can be calculated from UE side or from service platform.

7.2.3 Simultaneous Capacity

NB-IoT can support massive number of device connections as is specified in 3GPP TS 45.820 Annex E: Traffic Models.

But what is important for NB-IoT system is the simultaneous capacity which means UE initiate the service simultaneously. The simultaneous capacity is defined as how many users can complete the service during a short period of time,e.g. one second or one minute, if the users initiate access to the network simultaneously. The network can be deemed as good if more users can be supported simultaneously.

It should be mentioned that UE distribution of different cell levels can affect the capacity of NB-IoT network, with cell 0 coverage, the system can hold more users while cell 2 coverage hold less users for the same time period.

7.2.4 Service Throughput

Although NB-IoT is not so sensitive to throughput compared to other technology such as LTE and UMTS, for practical application, throughput still need to be concerned. It can indicate the channel utilization and efficiency capability of NB-IoT equipment.

The throughput is defined as the data volume to be transferred per second. A typical method of performing a measurement is to transfer a file from one system to another system and measure the time required to complete the transfer or copy of the file. The throughput is then calculated by dividing the file size by the time to get the throughput in megabits, kilobits, or bits per second.

Similarly, different cell level can affect service throughput in the same way as for service delay and simultaneous capacity. Usually UE with cell level 0 can get much higher throughput than cell level 1 and 2.

7.2.5 Service Success Rate

As is mentioned in Chapter 7.1, there are different traffic models for NB-IoT services. The models may be different from each other but the success rate can be evaluated in almost the same way. Take type 1 as an example. In order to complete a successful transmission of an exception report, UE needs to take the following steps:

1. Attach to the MME, which involves RRC establishment, authentication, security mode command and attach accept procedure.
2. Send one or more packets to application server via eNB and MME.

If the application server get the useful data, it is considered as a successful service and labeled the device as function normally. The service success rate can be monitored from application server as the number of normal devices divided by the devices deployed.

7.2.6 Summary

This chapter describes a methodology for estimating end-to-end performance in NB-IoT network. The results may be used in comparison with user-centric applications performance.