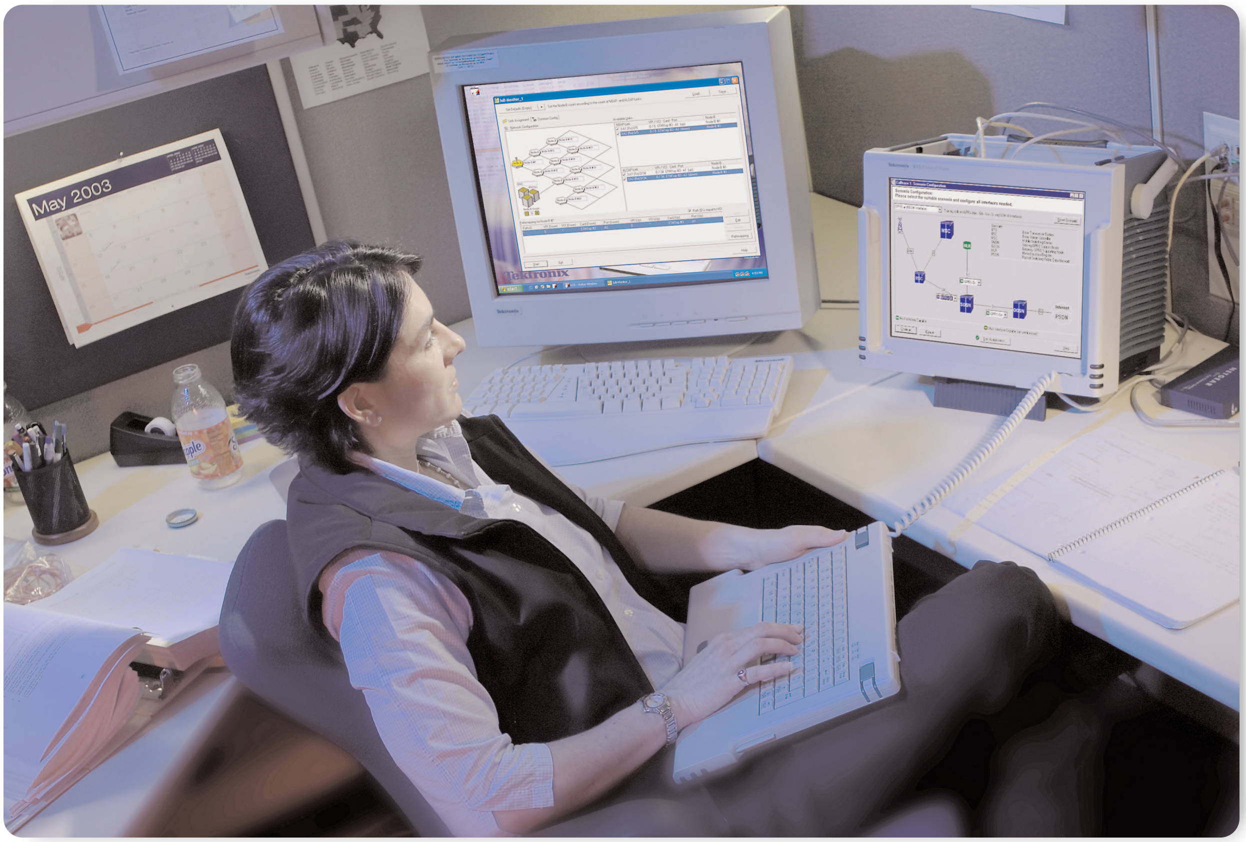
Exploit KPI Measurements for UTRAN Optimization



Introduction

The introduction of third generation mobile systems has enabled mobile network operators to offer a new range of mobile service to subscribers. The traditional voice offering is now complemented by a multitude of new services like video telephony, video streaming, video clip download and mobile web surfing.

The growth of the wireless market and the fierce competition between mobile network operators have created high customer expectations in terms of quality of service, not only for the business segment but also for the consumer segment.

Customer satisfaction is key for value creation and mobile network operators have to be able to monitor and manage the quality of the service they deliver to subscribers.

Mobile network operators face the challenge to identify the best metrics to describe the customer's perception of quality of service and develop a measurement infrastructure that enables measurement of these metrics starting from network performance data.

Benefits of Protocol Analyzers for Network Optimization

The traditional method of measuring performance, using the tools provided by individual network elements and service nodes, produces many KPIs. It is difficult to convert these to meaningful information reflecting the customers' perception of quality of service.

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Most of the time, KPIs produced by network elements monitor the underlying bearer network performance and define technology based network measurements, rather than service based measurements. Furthermore, in a multi-vendor network environment, KPIs from one vendor cannot be compared with KPIs from another vendor and do not provide a unique view on network performance.

Protocol analyzers represent tools to measure service degradation and to map service problems into the underlying network problems.

Since different services (voice, video, packet) have different quality requirements and the radio interface shall handle all of them, expert software applications on protocol analyzers are able to correlate radio interface KPI (e.g. BER, BLER, SIR, SIR target, Transmitted Code Power) with signaling KPI (e.g. dropped RRC connections), so it becomes essential to understand the influence of radio link quality on network behavior and eventually on the quality of service perceived by the end subscriber.

In addition, since expert software applications on protocol analyzers are able to track each single subscriber activity, KPIs can be calculated call per call (e.g. evolution of throughput over time for a packet switch connection with indication of relevant signalling events) therefore conveying the ultimate quality of experience perceived by subscribers.

Dimension Breakdown and Drill Down Approach

In order to carry out network optimization and identify the problem domain area, it is important to analyze the same set of KPI measurements from several perspectives.

KPI breakdown per service (e.g. voice, video, packet) helps identify which service is affected by poor quality. KPI breakdown per network element (e.g. cell, NodeB, RNC, SGSN, MSC) helps locate the domain area of the problem. KPI breakdown per subscriber eventually helps to identify which subscriber is affected by a quality of service degradation. This makes it possible to understand the impact of a network malfunctioning on the quality of experience.

Once a set of KPI is measured, having the ability to browse through the results, and narrow down the scope of the problem to identify the ultimate root cause, following the so called Drill Down approach is key to carrying out network optimization activities.

A common KPI, like call drop rate, is meaningless if it is not possible to break down the measurement per service, per network element and per subscriber. For example, a very high call drop rate for example can occur just for video calls and not for voice calls. The call drop rate might be higher in a portion of the network connected to one specific RNC, rather than in another area of the network connected to another RNC. Finally, the call drop rate may affect particular subscribers like roamers and business users that might be more sensitive to quality of service. Because of this, once a KPI has been measured it is mandatory to have access to the list of calls that generated that specific KPI, in order to understand the impact of the quality degradation to the final subscriber.

Attach Failure Rate – An example of a Key Performance Indicator

Protocol messages that indicate successful or unsuccessful procedures can be considered the first example of key performance indicators for network optimization.

If, for example, we define

Counter 1 = • of all Attach Request messages captured within a defined time period

Counter 2 = • of all Attach Reject messages captured within a defined time period

KPI: Attach Failure Ratio [in %] = $\frac{Counter2}{Counter1} \times 100$

The ETSI specification 3GPP 32.403 lists the most important success and failure ratios to be considered during network optimization activities.

All of these parameters give a first overview of network quality and behavior, and they help to identify problems in defined areas of the network.

For example, if Attach Failure Ratio is extremely high in a defined SGSN area this could indicate that there may be a specific problem in that area.

Once the Attach Failure Ratio KPI measurement indicates the presence of a network problem, the next step is identifying the root cause. The first action to perform is to analyze the reject cause values of the Attach Reject messages. Usually the sum of each possible Attach Reject cause value is displayed as a column in a table. Graphical overviews will most likely show bar diagrams or pie diagrams, where the most common reject cause values become evident.

Another problem emerges if the results shown in Figure 1 are analyzed, the reject cause value itself is not enough to find the root cause of the problem. Sometimes it is not even enough to decide if it indicates an erroneous procedure or not. Additional analysis is necessary.

From 3GPP 24.008 (Mobility Management, Call Control, Session Management), it is known that the cause value “network failure” is used “if the MSC or SGSN cannot service an MS generated request because of PLMN failures, e.g. problems in MAP.”

So the root problem of this Attach Reject seems to be somewhere inside the core network. This can be analyzed in more detail by examining the parameters of the Attach Request messages (ATRQ) that are essential for routing core network messages, especially IMSI, in relation to appropriate Attach Reject (ATRJ) cause values. Here we have an example

Date	Time	Attach Req.	Attach Accept	Attach Rej. total	Attach Rej (Network Failure)
31.03.2004	18:11:23	95	13	27	27

▶ **Figure 1.** *Event Counters for Attach Request and two different causes of Attach Reject.*

of a procedure that requires context-related filtering, extracting, and storing call parameters belonging to single user and/or call procedures.

In the example shown in Figure 2, IMSI analysis revealed that most attach attempts rejected with cause value "network failure" were sent by roaming subscribers. An investigation showed that there were no roaming contracts signed between the monitored PLMN operator and the Home PLMN operator of the roamers. Hence, SGSN was not able to set up a connection to the subscriber’s HLR, which was indicated by cause value “network failure”. This may not be a satisfying result from the roaming subscriber point of view, but the network operator sees that the network executed the correct procedure.

The root cause in this case was quite easy to find, based on different, flexible presentation of analyzed data. (1st step: show number of ATRJ messages sorted by included cause value, 2nd step: show IMSI related to Attach Reject with cause = “network failure”).

However, not all “network failures” indicate a correct behavior of the network as in the case described above. See figure 4 of this document and read appropriate chapter "MM/SM/CC Latency" to get a typical example of a "bad case" indicated by same reject cause value "network failure". It is a challenge to distinguish between “good cases” and “bad cases” that also show the same reject cause value, but have been caused by incorrect network behavior, for example interconnection problems between home and visited PLMN.

Radio Link Key Performance Indicators

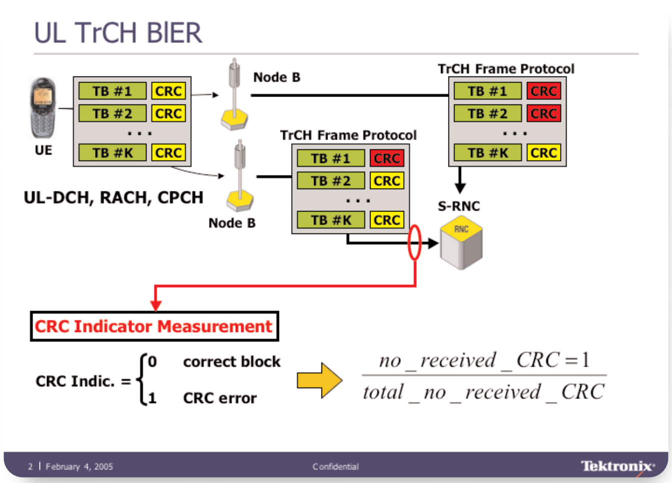
The most important radio link performance indicators for assessing the status of the WCDMA radio interface are the following:

– Uplink Transport Channel Block Error Rate (BLER)

The uplink transport channel block error rate BlER is not a specified measurement value in 3GPP standards, but provided by Tektronix KPI measurement. The serving RNC measures BLER in a network environment, so there is no external reporting of it.

Of course, it can happen that a transport block is received via all radio links with CRC error. In this case a block error is detected. The serving RNC counts for each transport channel of a UE the total number of received transport blocks (the same transport block from different radio links is counted once), and the number of detected block errors (CRC error). The ratio between the two is the transport channel block error rate (TrCH BlER).

The serving RNC uses the TrCH BlER for radio management (handover decisions, measurement control trigger) and for outer loop power control.



– Quality Estimate and Uplink Bit Error Rate (QE and BER)

The quality estimate (QE) is carried in DCH-FP DCH DATA FRAME protocol data units over Iub. It indicates the quality of the received signal in terms of the bit error rate. The serving RNC uses the QE field to perform soft handover combining. This means that when the same transport block is received from several cells (soft handover) and the CRC indicator is +1 or 0 for all received signals, the best QE (lowest value) is taken. All other signals are discarded. Furthermore, a RNC vendor can choose to use the QE as an input parameter for outer loop power control.

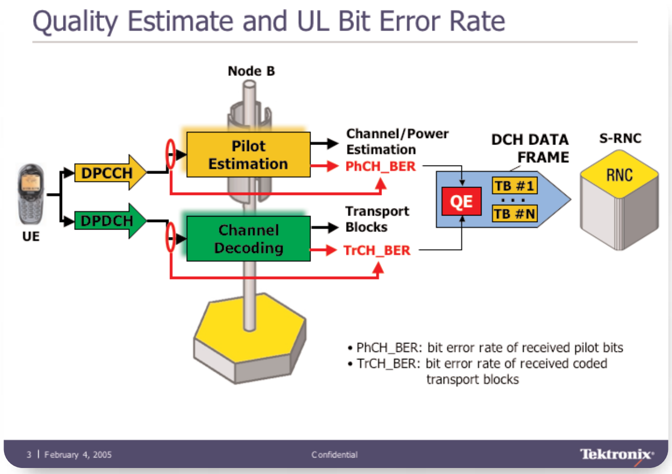
The QE field uses either of two Node B measurements:

Physical Channel Bit Error Rate (PhCH_BER): The PhCH_BER is the estimated bit error rate of the DPCCH pilot bits of a radio link or radio link set.

Transport Channel Bit Error Rate (TrCH_BER): The TrCH_BER is the estimated bit error rate of the DPDCH of a selected transport channel before channel decoding.

Which of the two bit error rates is chosen as QE depends on the radio link configuration. The NBAP information element “QE-selector” is an enumeration with values “selected” and “non-selected”. If all DCH of UE that are multiplexed onto the same frame I protocol instance (co-ordinated DCH) have “QE-selector” = “non-selected”, then the QE is equal to the PhCH_BER. On the other hand, if a certain number of co-ordinated DCH have “QE-selector” = “selected”, then the QE shall be equal to the TrCH_BER of these DCH.

The information element "QE-selector" is used during any NBAP procedure that allocates new DCH. This can be the following NBAP procedures: "RADIO LINK SETUP FDD". "UNSYNCHRONIZED RADIO LINK RECONFIGURATION FDD" and "SYNCHRONIZED RADIO LINK RECONFIGURATION PREPARATION FDD". Setting of "QE-selector" depends on installed RNC configuration.



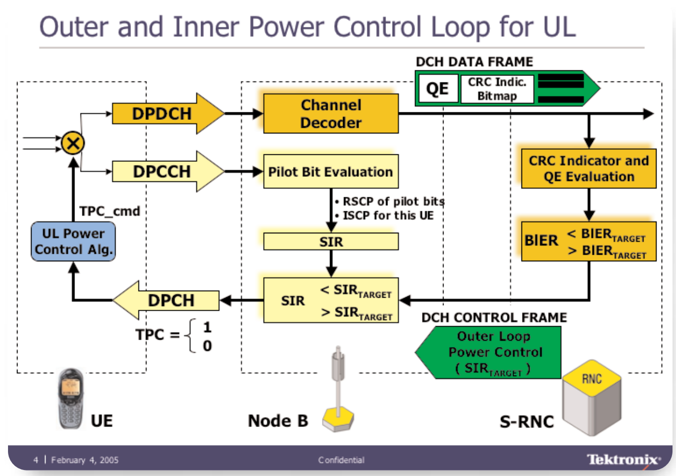
– Outer and Inner Power Control Loop for Uplink

The closed loop power control for uplink DPDCH and DPCCH provides additional measurement capabilities in UTRAN. The closed feedback loop for uplink power control is split into two feedback control loops running on different time scales. The inner loop is directly controlling the uplink power. The Node B measures the DPCCH pilot bit power (RSCP) and calculates from it the signal-to-interference ratio (SIR) of the signal. This is then compared against a SIR TARGET value. If the measured SIR is less than SIR TARGET, then the Node B sends in the associated downlink DPCH a transmit power command TPC = 1, which means that the uplink power should be increased. Otherwise TPC = 0 is sent and the uplink power should be decreased.

The UE evaluates the received TPC signals. In soft handover scenarios, there is one TPC coming from every cell per slot (15 slots per 10 ms radio frame). The UE has to combine all TPC signals and derive a TPC command TPC_cmd from it. The TPC_cmd can be +1 (increase UL power), -1 (decrease UL power) and 0 (keep UL power).

The second control loop is between serving RNC and Node B and concerns the setting of SIR TARGET.

SIR TARGET as well as SIR ERROR reports are monitored by Tektronix' KPI solution.



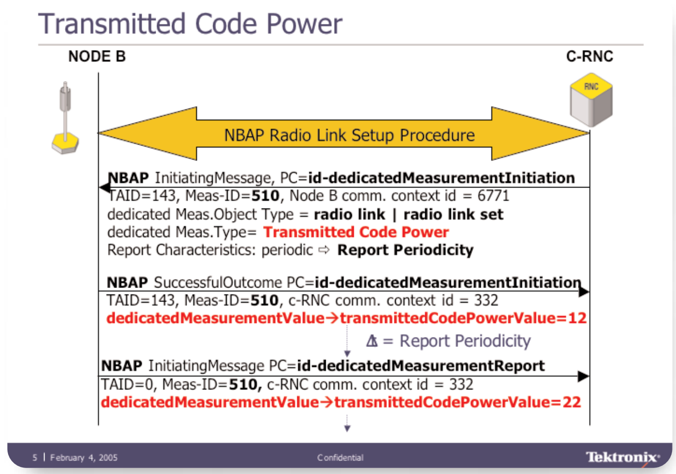
– Transmitted Code Power

For dedicated physical channels the Node B can report the used transmission power on the relevant downlink DPCH. This measurement is provided by the so called Transmitted Code Power (UTRAN CODE POWER). It can be used by the RNC to trigger UE measurements on inter-frequency or inter-RAT neighbor cells.

The measurement is done on the downlink DPCH pilot bits. During setup of a radio link or radio link set, the RNC indicates three power offsets PO1, PO2 and PO3 to the Node B. The parameters can be found in the "initiating message" of the "RADIO LINK SETUP" procedure. Of interest here is the value PO3; it indicates the power difference of data part (coded DCH bits) relative to the power of the DPCH pilot bit field. PO3 can be set in a range between 0 dB and 6 dB, in 0.25 dB steps. The transmitted code power is the power of the pilot bits. Using the power offset it is possible to determine the power of each of the various bit fields in a DPCH slot.

The Node B reports the transmitted code power as part of the dedicated measurement report procedure. It can be found as information element "Transmitted Code Power Value" inside "Dedicated Measurement Value". Two procedures provide this parameter: "Dedicated Measurement Initiation" (successful outcome message) and "Dedicated Measurement Report" (initiating message).

If a UE uses several channelization codes in parallel (multi-code usage) and thus has not a single radio link, but a radio link set, then the transmitted code power can be measured only for the whole radio link set. This is because DPCH pilot bits exist only for the very first channelization code, but not for second or third, etc.

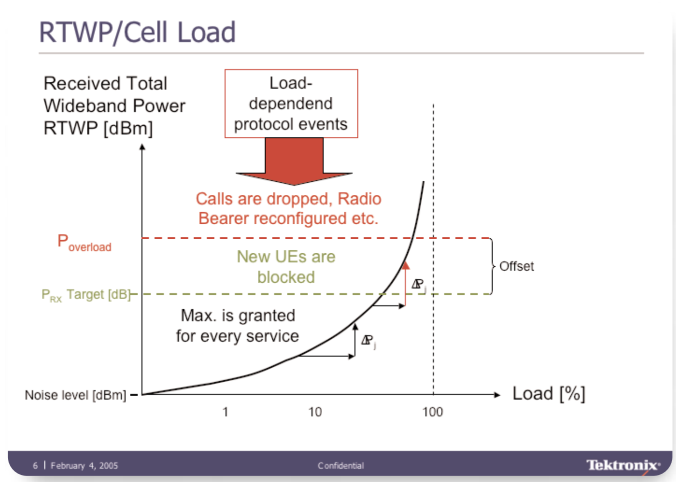


– Received Total Wideband Power/Cell Load

A rising RTWP level indicates rising load in the cell. Admission Control and Packet Scheduler in SRNC will react to RTWP indication.

If Prx Target is reached new UEs will be not allowed to enter the cell. For example, a RRC Connection Reject message is sent if a RRC Connection Setup is requested.

If the overload threshold is reached, the SRNC will react with reconfiguration and reallocation of dedicated cell resources: decreasing data transmission rates for PS services, intra-cell handover (channel type switching) and also network-controlled drop of single calls can be monitored.



An example of the Influence of Radio Link Performance on Customer Perceived QoS

Radio link performance parameters have direct impact on the service quality perceived by subscribers. This is especially evident in UMTS cells with high load when the Received Total Wideband Power rises above a certain threshold.

As shown in figure 2, RTWP measurement is used by power-based admission control (power-based AC, which is used by most network operators) to calculate the impact that a new connection will have on all other connections within the cell. The upper boundary for the AC operation is defined by the maximum allowed deterioration of the quality for the existing links (=the maximum allowed deterioration of the path loss). This limit is usually defined as PRX Target [dB].

Now, if RTWP level exceeds PRX Target, a chain reaction can be monitored on Iub: CRNC of the overloaded cell requests SRNC to re-calculate the already existing bearers. New priorities will be assigned dependent on spreading factor. Services/bearer using high spreading factors will be ordered to lower their data transmission rate. This will especially impact data transmission rates and throughput of PS and multi-media calls. Background PS calls will probably be ordered to continue in CELL_FACH state, which will result in a peak of RRC Physical Channel Reconfiguration procedures, which belong to a group of intra-cell handovers. This means handover rates will show a dramatic peak for this cell, the possibility of handover failures will be high, and handover KPIs might indicate a higher HO failure rate. QoS for PS calls will be lowered dramatically as well and many other unforeseeable effects may happen that still need to be investigated.

Radio Resorce Control protocol Key Performance Indicators

RRC connection attempts

Before a UMTS mobile (in following text called User Equipment, UE) can exchange any kind of signalling with core networks domains (which includes all signalling for mobility management and CS/PS call setup) it needs to have an active RRC connection with its Serving Radio Network Controller (SRNC). Hence, it is important to know the number of RRC connection attempts. This number must also take into account if UE changes its RRC state from CELL_PCH or CELL_URA into CELL_FACH or CELL_DCH, because only in the latter two RRC states it is able to exchange signalling with core network elements like MSC and SGSN.

On behalf a of specific information element a mobile originated and mobile terminated attempt rate are defined.

The analysis of this key performance indicator allows you to:

– detect problems in interaction between UE and the network in an early stage (setup of RRC connection, which is prerequisite to exchange NAS signaling for mobility management, call control and session management)

– rate mobile originated and network-triggered initial UE access

– detect cells with high initial access rate

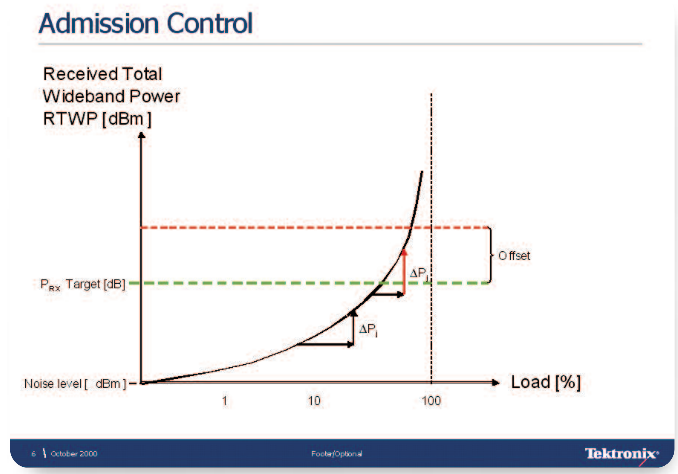
RRC Congestion/Dropped Connections

Dropped RRC connection attempts can be identified on behalf of the following messages:

– RRC Connection Reject

– RRC Connection Release following the Cell Update Request

Based on the number of dropped RRC connections it is possible to define a RRC connection success/drop rate. This gives an overview of failed call attempts before any kind of Non-Access-Stratum (NAS) signalling is exchanged and helps to identify problems in the Access Stratum.



▶ **Figure 2.** *Relation between RTWP and Cell Load.*

RANAP protocol Key Performance Indicators

RANAP Release Cause

The RANAP Iu Release Procedure shows if RANAP connections on IuCS and IuPS are released in a normal way or if they are dropped due to errors.

RANAP Release Request Cause

With Iu Release Request, SRNC requests the deletion of an ongoing RANAP signaling connection on Iu. Often simultaneously, Radio Access Bearers (RAB) are released. Since many cause values do not contain enough information to identify specific errors, further drill-down analysis focusing on a call per call analysis is necessary. For example cause “user-inactivity” indicates both release of RAB in case of timeout for user data transfer following channel type switching on Iub interface (normal procedure), or release request after losing radio contact with UE (abnormal procedure).

RANAP Latency/Response Time

Average latency for RANAP procedures, especially RAB Assignment and Relocation procedures.

NBAP Failure Rates

On rate is based on counting NBAP Unsuccessful Outcome messages, which are displayed following their procedure codes.

In addition other error messages, such as NBAP Radio Link Failure Indication, need to be counted. Here a call based analysis is necessary to distinguish between real radio link errors and radio link failures sent following successful hard handover procedures.

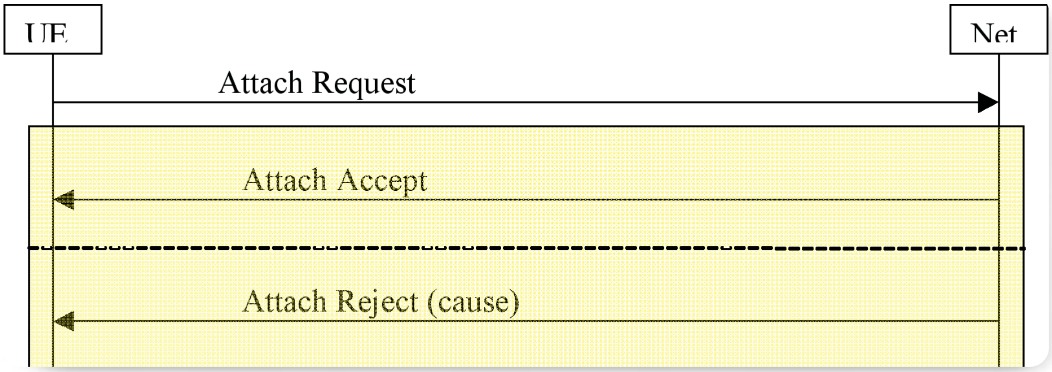
The analysis of this key performance indicator allows you to:

– detect general errors in communication between Node B cells and CRNC

– detect if UE loses radio contact with cell

– detect errors in setup of common and dedicated NBAP measurement procedures

– detect unavailability of resources like cells, physical channels, transport channels



▶ **Figure 3.** *MM/SM/CC Procedure with Alternative Answer.*

ALCAP Failure Rates

This helps to identify problems with setup of physical transport bearers for DCH on Iub and Iur and Iu bearer on IuCS. In addition to successful and unsuccessful ALCAP call attempts, the number of CONFUSION messages needs to be counted, to indicate general problems within active ALCAP contexts.

The analysis of this key performance indicator allows you to detect all possible problems related to setup and modification of physical transport bearers on Iub, Iur, and IuCS (user plane) interface.

Iu MM/SM/CC Procedures Counters, Success Rate, Failure Cause Analysis

The analysis of this key performance indicator allows you to:

– get a complete overview of successful/unsuccessful communication between UE and core network on NAS level

– identify problems related to specific UEs (identified by IMSI, IMEI etc.) and network elements (e.g. specific APN)

All MM/CC/SM (or NAS Signaling) analysis is typically based on data recorded on IuCS and IuPS interface.

Many MM and SM procedures follow the same scheme shown in next figure. A procedure (e.g. GPRS Attach procedure) is requested and either accepted or rejected by the peer entity:

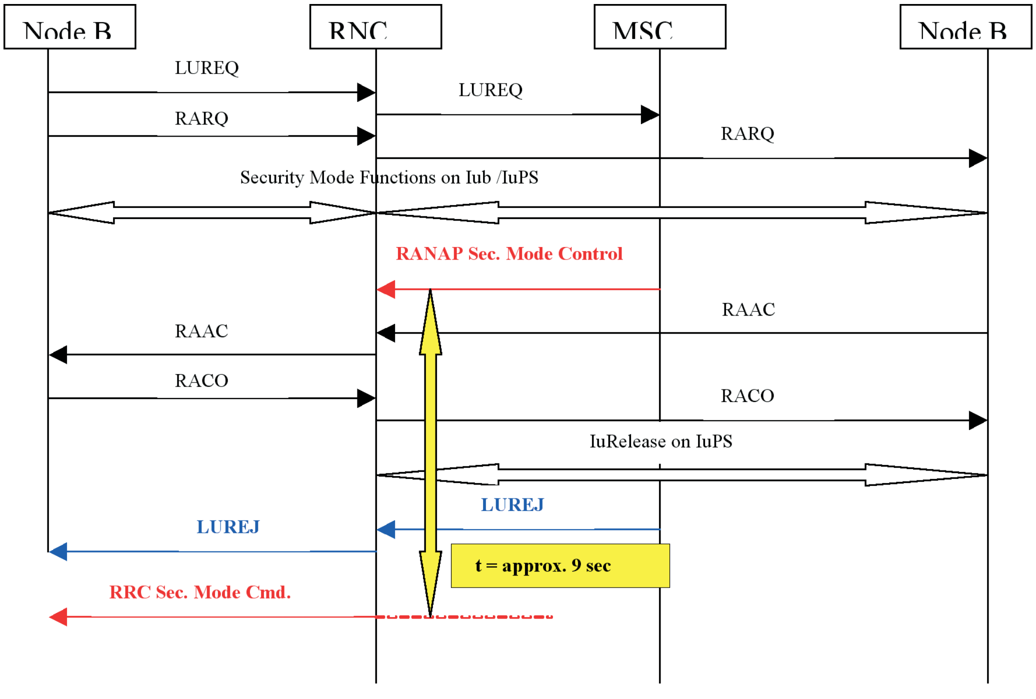
All measurements and rates as recommended in 3GPP 32.403.

Iu GMM/SM/CC Latency

Average, Min, and Max response time is recorded for the following procedures: Attach, Activate, Create PDP Context, Modify PDP Context, Delete PDP Context, Deactivate, Detach, Routing Area Update.

Latency measurement can become very important to identify the root of troubles, as the following example shows:

The call flow diagram in Figure 3 shows that MSC rejects a location update or IMSI attach procedure (need to check details of LUREQ message), because RNC is obviously not able to proceed with Security Mode functions within the necessary time. A classic location update failure rate would see the problem on the MSC side. Only with multi-interface call trace function and call-related latency measurement does it become possible to identify the RNC as the cause of the problem in the network.



▶ **Figure 4.** *Case of Drill-down Analysis based on Latency Measurement.*

RLC Throughput

Throughput UL and DL is measured on behalf of user data statistics at the RLC layer. The measured value is compared with negotiated QoS values to prove if real conditions on the user plane correspond with settings coming from the control plane or not.

TCP Round-trip Time

This TCP Round-trip time estimation is based on definitions made by Karn and Partridge (1988), a well-defined measurement process in TCP/IP networks that is with adapted to be used for UMTS user plane performance measurement and optimization.

Application Throughput

This KPI gives a detailed overview of PS call throughputs sorted by type of TCP/IP application layer protocol (HTTP, FTP etc.), and on a call-by-call basis.
This enables you to detect bottlenecks on Iub, IuPS interface.

Handover Rates and Statistics

Statistics on the handovers support the identification and the analysis of handover problems in the different UMTS-only scenarios (intra-RNC, inter-RNC, etc.). The statistics are:

a. Number of HO per cell

b. Number of faulty HO per cell

c. Number of active subscribers per cell

The counters and KPIs are basically derived from 3GPP 32.403.

The analysis of this key performance indicator allows you to:

– Identify problems with handover execution that will impact QoS and call drop rates.

– Get an overview of handover by handover type.

– Identify cells with high handover rate and use handover KPI as a metric for cell/radio network optimization

Conclusion

Key performance indicator measurements help to report the presence of problems within mobile networks. Once the problem has been reported, it is essential to drill down to the root cause within the network. Key performance indicators with breakdown per service (e.g. voice, video, packet), per network element (e.g., cell, NodeB, RNC, SGSN, MSC) and call per call per subscriber (e.g. IMSI, MSISDN) is essential to navigate through data results and to narrow the scope of the problem to isolate the ultimate root cause.

Protocol analyzers help in this analysis by providing an independent third party analysis tool for mobile network performance.

Contact Tektronix:

ASEAN / Australasia / Pakistan (65) 6356 3900
Austria +41 52 675 3777
Balkan, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium 07 81 60166
Brazil & South America 55 (11) 3741-8360
Canada 1 (800) 661-5625
Central Europe & Greece +41 52 675 3777
Central East Europe, Ukraine and Baltics +41 52 675 3777
Denmark 80 88 1401
Finland +41 52 675 3777
France & North Africa +33 (0) 1 69 81 81
Germany +49 (221) 94 77 400
Hong Kong (852) 2585-6688
India (91) 80-22275577
Italy +39 (02) 25086 1
Japan 81 (3) 6714-3010
Luxembourg +44 (0) 1344 392400
Mexico, Central America & Caribbean 52 (55) 56666-333
Middle East, Asia and North Africa +41 52 675 3777
The Netherlands 090 02 021797
Norway 800 16098
People's Republic of China 86 (10) 6235 1230
Poland +41 52 675 3777
Portugal 80 08 12370
Republic of Korea 82 (2) 528-5299
Russia, CIS & The Baltics 7 095 775 1064
South Africa +27 11 254 8360
Spain (+34) 901 988 054
Sweden 020 08 80371
Switzerland +41 52 675 3777
Taiwan 886 (2) 2722-9622
United Kingdom & Eire +44 (0) 1344 392400
USA 1 (800) 426-2200
USA (Export Sales) 1 (503) 627-1916

For other areas contact Tektronix, Inc. at: 1 (503) 627-7111

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