Identifying Failures and Quality Problems in GPRS Networks

Hands-on information on how to use protocol analyzers to determine failures and quality problems in today's GPRS networks.

GSM has provided for circuit-switched data services since 1992. However, the maximum data rate is limited to 14.4 kbit/s without timeslot bundling, and most operators support only 9.6 kbit/s. More important is that users must accept duration-based charging even for bursty traffic type services like surfing the Internet. These liabilities are exactly what led to the standardization and development of the General Packet Radio Service (GPRS) as expansion for regular GSM networks.

Network operators must consider that today's GPRS networks differ from each other. In addition, some features have not been implemented yet, such as PBCCH (Packet Broadcast Control Channel), the PCCCH (Packet Common Control Channel), different Network Operation Modes, and different options to establish a PDP context, and they will certainly help optimize GPRS performance from the customer's perspective.

Another important issue concerning error detection, failure statistics, and performance measurements is the dearth of long-term experience and an unfortunate lack of trust by many optimization engineers in the GPRS mobile stations that are available today. Yet another hurdle that initially has been neglected during the implementation phase is that GPRS optimization not only requires extensive knowledge of GSM and GPRS, but also a thorough understanding of TCP/IP networking.

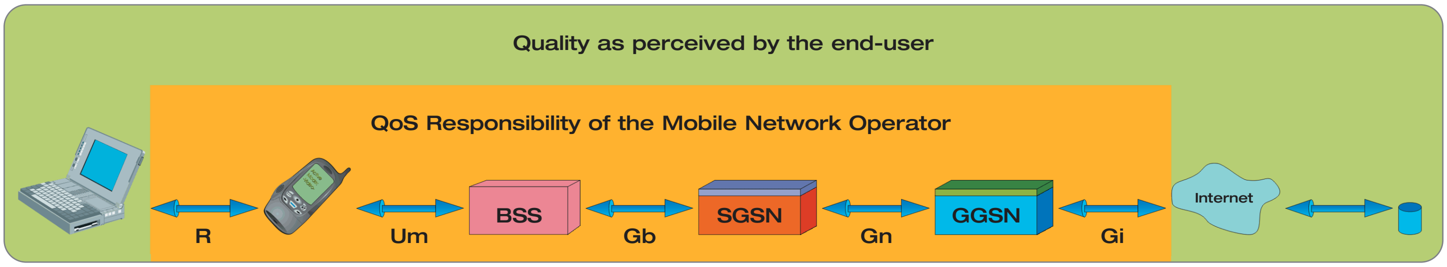


__Figure 1.__ Different perspectives of network quality.

GPRS provides volume based charging and higher throughput rates than GSM and most importantly, the possibility to stay online permanently without additional cost. Finally, GPRS mobiles have become available on a broader scale, and network operators are eager to optimize their networks for GPRS traffic. That raises the issue of exactly what the most important characteristics are by which an end-user determines the quality of a telecommunication service such as GPRS. Of course, there may be a variety of responses depending on which user is asked. In any case, the following issues appear to be the most common ones facing operators of GPRS networks:

- **Technical in-complexity**
  Operators shouldn't need to have a master's degree to enable and use the GPRS.
- **Price**
  Even though customers understand volume based charging and the advantage of being online permanently, if the transfer of three or four e-mails costs more than a few cents, they will be reluctant to use the GPRS.
- **Availability**
  Customers may need the GPRS to be available everywhere and all day long. In that respect, they may not be entirely happy when traveling abroad. While their network operator supports international roaming, GPRS is mostly not available abroad.
- **Throughput and Speed**
  Customers may have the impression that the speed of GPRS depends on one's whereabouts. For instance, users may encounter very poor throughput rates on a laptop with GPRS when surfing the Internet in metropolitan areas at certain times.

These are only a few examples of end-users' remarks when talking about GPRS. The protocol analyzer can't resolve the issue of setting up GPRS between an end-user's terminal and the network, nor can it help to introduce an appropriate pricing structure. However, the protocol analyzer is very useful in following up on procedural errors that occur during operation. In that respect, the protocol analyzer will never be a tool to resolve a problem. Instead, it will guide the technician to the source of the problem, whether it is hardware or software. The protocol analyzer is also capable of providing statistical information about the use of GPRS at certain times and certain places. This application note focuses on these topics and provides useful suggestions on how to effectively use a protocol analyzer to optimize GPRS operation.

We will focus our discussion around the K1205, Tektronix' powerful protocol analyzer that is frequently used by operators and equipment vendors.

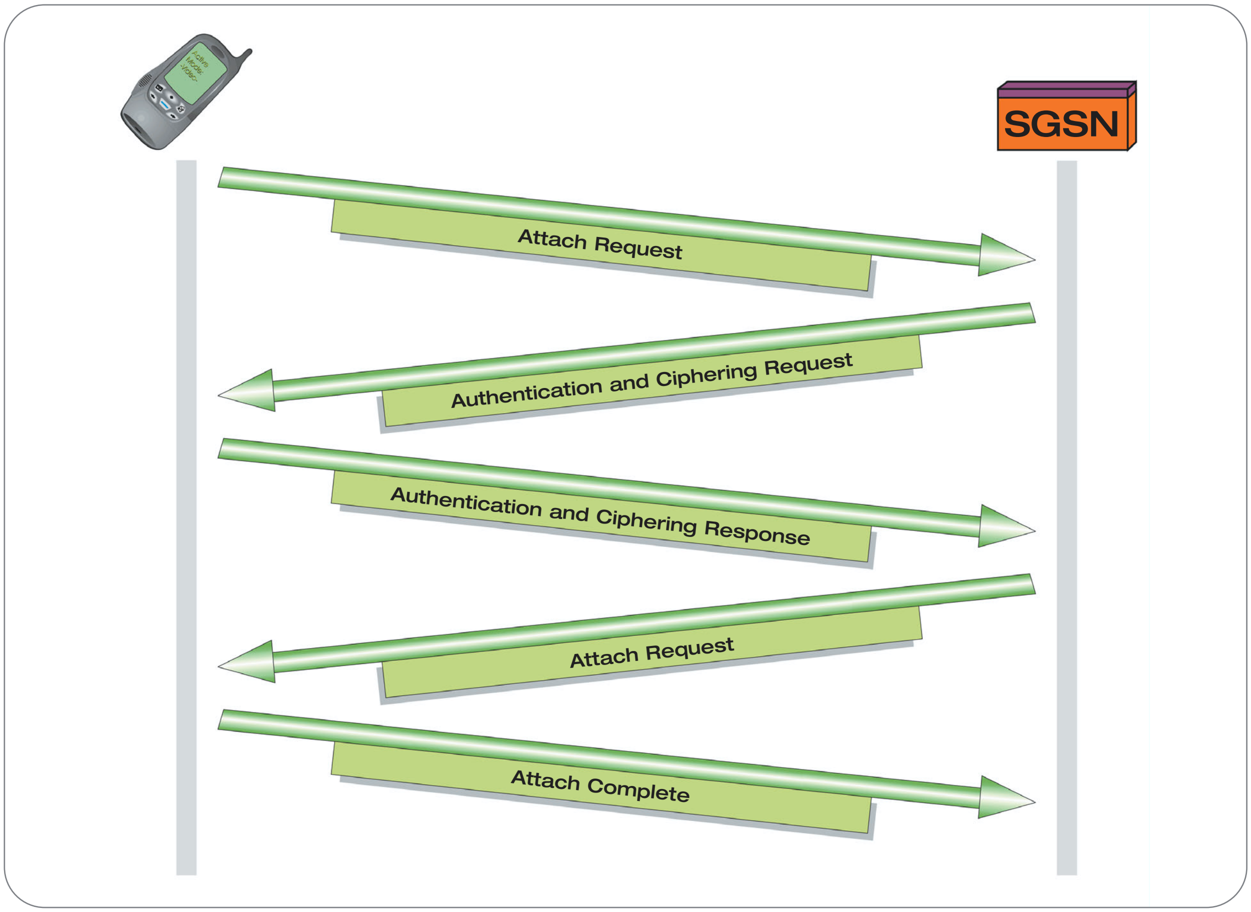


Figure 2. *The GPRS attach procedure initiated by the mobile station in network operation mode II or III.*

Important GPRS Procedures

GPRS – Attachment and Detachment

By means of the GPRS attach procedure, users register the GPRS of their mobile network operator. The network and the mobile station establish a GPRS Mobility Management context (GMM context). The network (the SGSN) is now aware of the user's presence. Usually, the mobile phone will perform the attach function autonomously when the power is on. As Figure 2 illustrates, the attachment is performed between the mobile station and the SGSN, although the SGSN also needs to communicate with the HLR of the end-user. All related messages can be recorded with the K1205 on the Gb interface between the PCU and the SGSN. If the K1205 is connected to the Gb interface at the location of the SGSN, then the Gr interface between the SGSN and the HLR can also be traced. The figure title also mentions the possibility of different network operation modes. We will assume that you are aware of these network operation modes. References to relevant literature are provided at the end of this document.

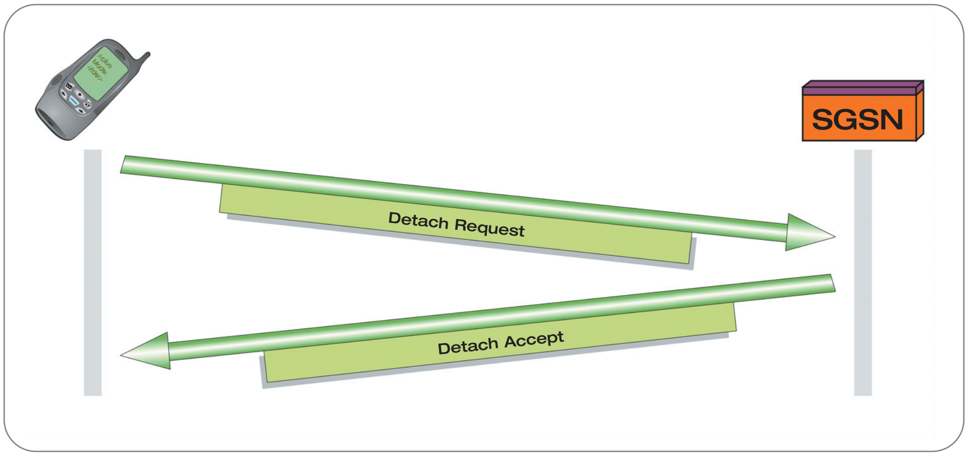


Figure 3. *The GPRS Detach Procedure initiated by the mobile station in network operation mode II or III.*

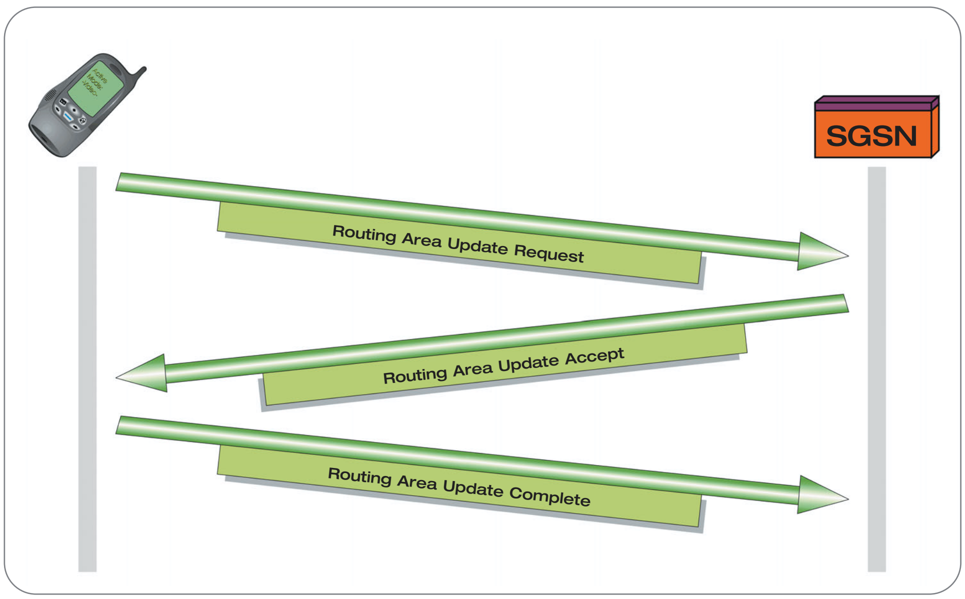
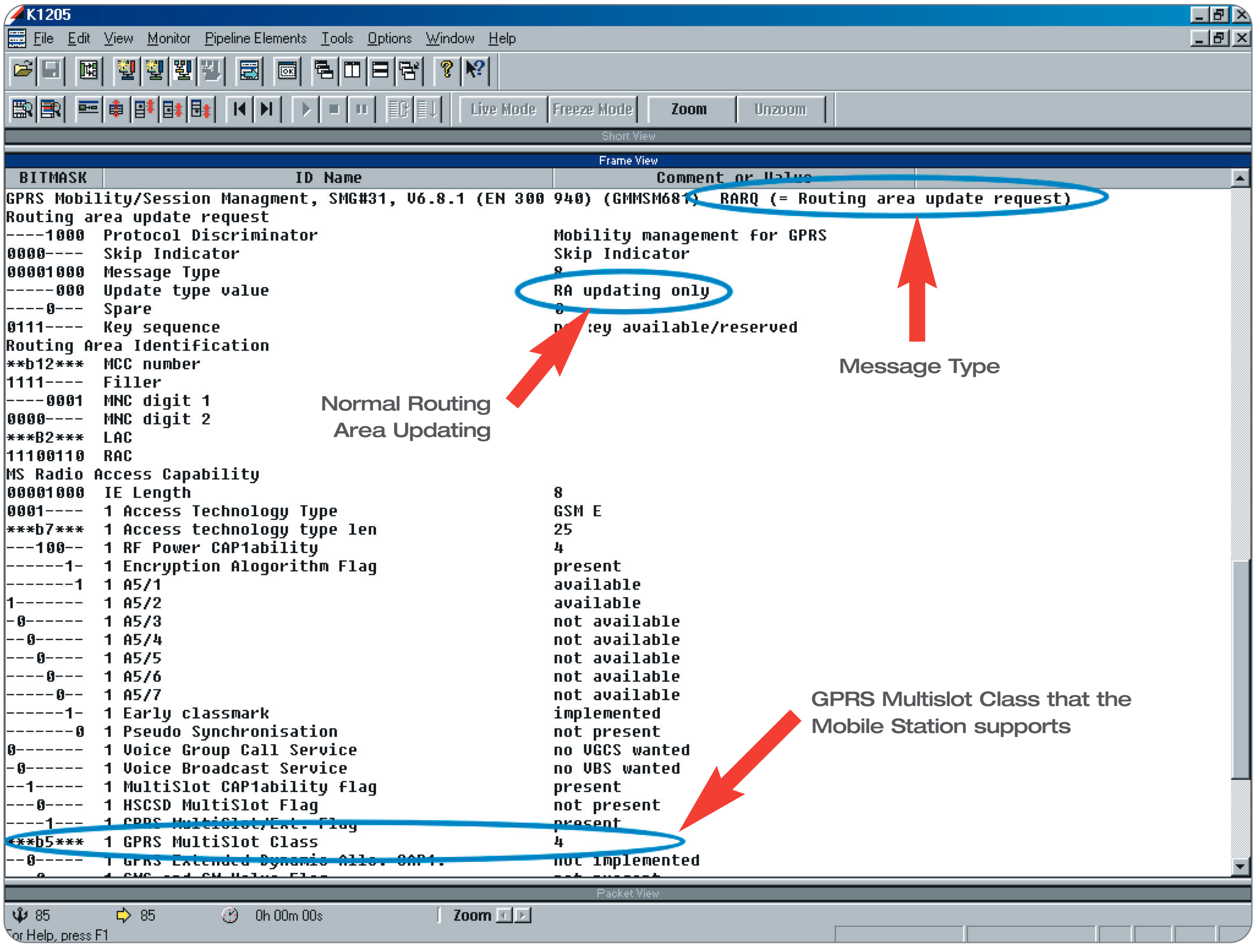


Figure 4. *The Routing Area Updating Procedure.*

Note that even after attachment, users are still not able to surf the web without having an IP address. Still, after GPRS attachment, users are able to transmit and receive short messages (SMS) by means of the GPRS. The opposite function, the detachment of a mobile station, is usually done with the power off and is initiated by the mobile station. By means of the detach function, users de-register from the network. Note that detachment can also be initiated by the network, such as to enforce re-attachment after procedural problems during routing area updating.



▶ ***Figure 5.*** *Extract from a Routing Area Update Request message (normal routing area updating) that was recorded by a K1205.*

Routing Area Updating (Periodic and Non-Periodic)

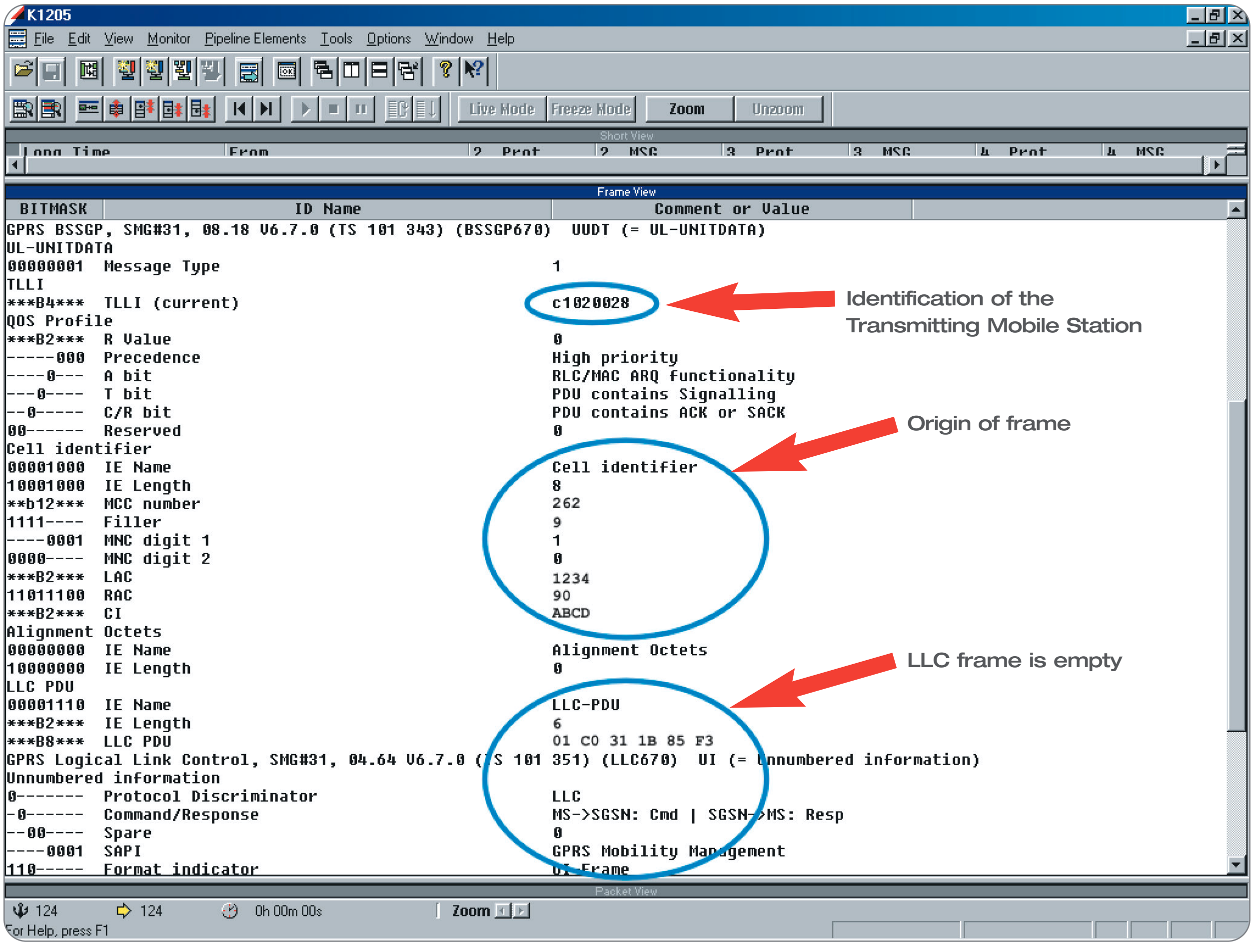
The Routing Area Updating Procedure is always initiated by the mobile station. There are two particular reasons for a mobile station to perform a routing area update:

- Upon changing the serving cell when this new serving cell belongs to a different routing area. Note that opposed to circuit-switched GSM the routing area update procedure is also performed while the mobile station is in packet transfer mode (non-periodic routing area update).
- Upon expiration of the periodic routing area updating timer (T3312 ≈ 54 min), the mobile station will perform the periodic routing area updating procedure even without change of the routing area.

The particular type of routing area update that is actually performed by a mobile station is indicated within the Routing Area Update Request message, as seen in Figure 5.

Cell Updating

Circuit-switched GSM and packet-switched GPRS both use attach and detach procedures. The location area updating procedure in circuit-switched GSM and the routing area updating procedure in packet-switched GPRS also are used. There appear to be similar procedures for both technologies; however, cell updating is one procedure that is completely new with GPRS. The best analogy to this GPRS-specific procedure is the handover procedure in circuit-switched GSM. Note that this analogy only applies under certain conditions.



▶ ***Figure 6.*** *Uplink LLC frame transfer over the Gb interface.*

The cell update procedure is initiated and performed by a GPRS-attached mobile station upon cell reselection within the same routing area, if the GMM READY timer (T 3314/Default value = 44 s) hasn't expired. The actual timer value can be negotiated between the mobile station and the SGSN during the attach and routing area updating procedures. The READY timer is restarted by the mobile station after having sent an LLC frame and by the SGSN (for a given mobile station) after having received this LLC frame. The cell updating procedure consists of the mobile station sending a possibly empty LLC frame to the SGSN. If the LLC frame is empty, or contains payload or signaling information, it depends only on the output queue of the mobile station. If the mobile station has to transmit information, then the LLC frame will be used as a bearer. Otherwise, the LLC frame will remain empty.

This raises the issue of how meaningful it is to transmit an empty LLC frame. At first sight, transmitting an empty LLC frame doesn't make any sense. However, looking at how this frame is transferred over the Gb interface, as in Figure 6, it becomes more obvious. Before relaying an LLC frame towards the SGSN, the PCU will, in any case, append the cell identity and location area information of the LLC frame's origin. Therefore, the SGSN is informed about the new serving cell of the mobile station. Consequently, and only while in GMM READY state, the SGSN is aware of a mobile station's location, not only down to the routing area level (≥ 1 cell), but down to the cell level (= 1 cell).

Why this is done? To skip the paging and paging response procedure if the SGSN has to transmit data to the mobile station while in GMM READY state. This way of processing copes with specifics of many Internet applications that ask for short and bursty transmission periods with idle phases in between.

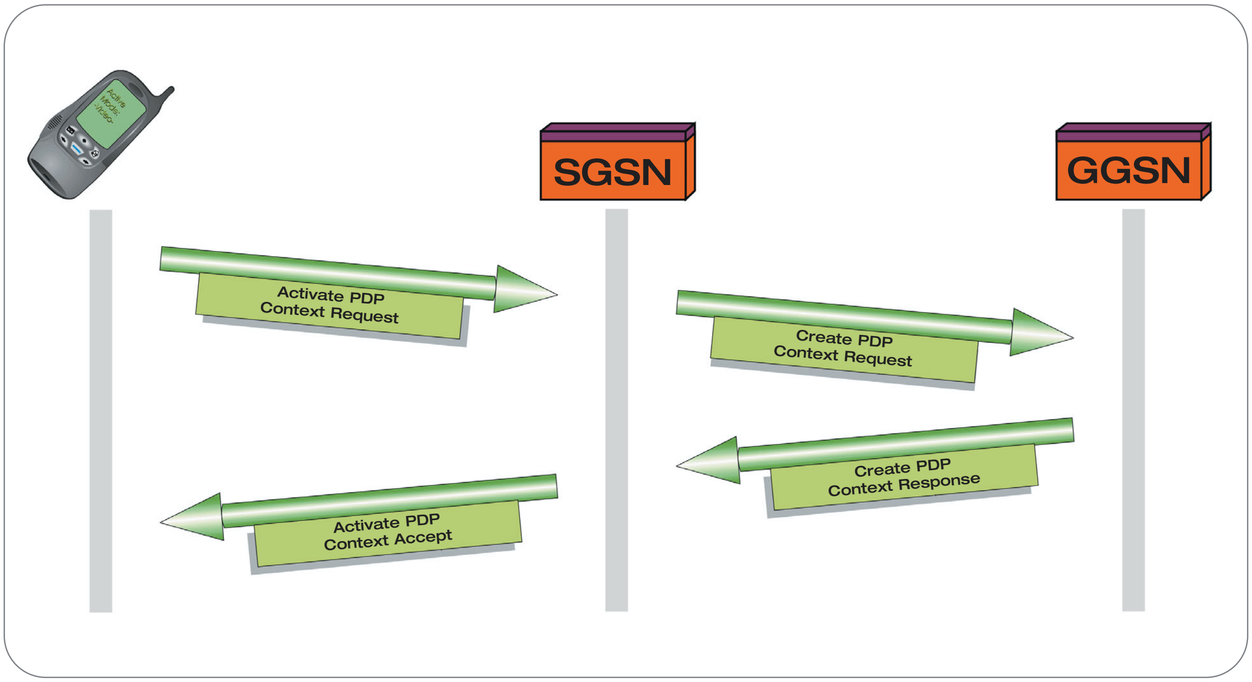
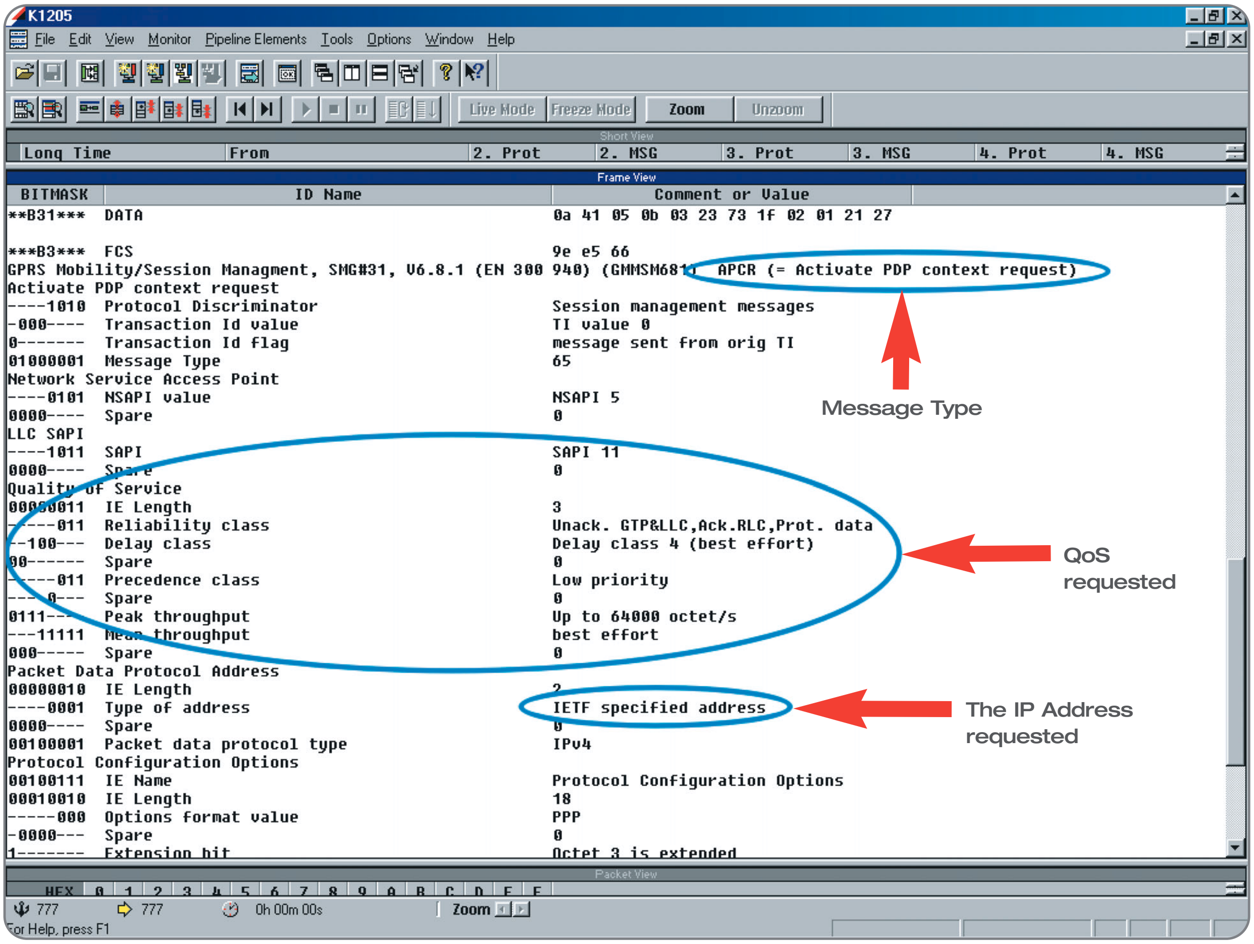


Figure 7. The PDP Context Activation Procedure.

PDP Context Activation and Deactivation

By means of the GPRS Attach Procedure, users register to the network. Even when registered, users do not yet have an IP address to exchange data with a foreign network. Only short messages can be sent and received using the GPRS. Therefore, users need to establish a Packet Data Protocol Context (PDP context) before any other kind of data transfer can be done. As opposed to the prior procedures, the PDP context activation procedure illustrated in Figure 7 not only involves the SGSN, but also the GGSN.



▶ ***Figure 8a.*** *Activate PDP Context Request message (recorded by a K1205 on the Gb interface).*

Another difference from the prior GMM procedures is that PDP context activation is not performed autonomously by the mobile station; rather, it requires the explicit request of the users. Users also need to initialize configuration options within the mobile station or the terminal equipment to identify where to obtain the IP address from or which quality of service shall be used. Figures 8a and 8b illustrate examples for the message flow between SGSN and mobile station. Only after a successful PDP context activation are users finally able to use GPRS for Internet access.

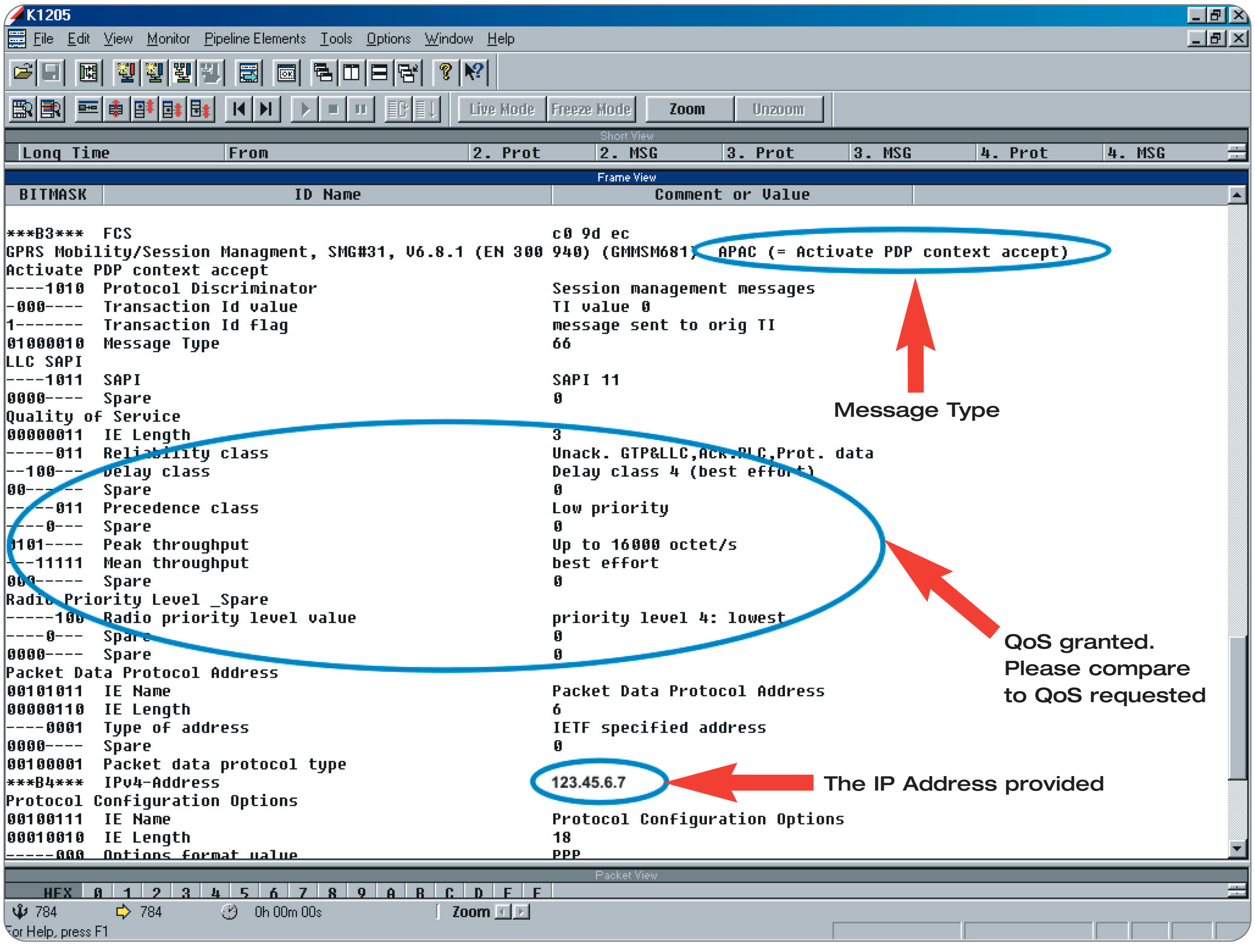


Figure 8b. *Activate PDP Context Accept message (recorded by a K1205 on the Gb interface).*

Establishment/Release of a Temporary Block Flow

Within the BSS, the K1205 is most frequently used on the Gb interface between the PCU and the SGSN. This is due to the fact that all GMM or SM messages, as well as IP data packets, can be perfectly recorded and decoded on the Gb interface, as illustrated in Figures 8a and 8b. The K1205 is also able to record the message flow on all remaining interfaces, for example, on the Abis interface between the PCU and the BTS.

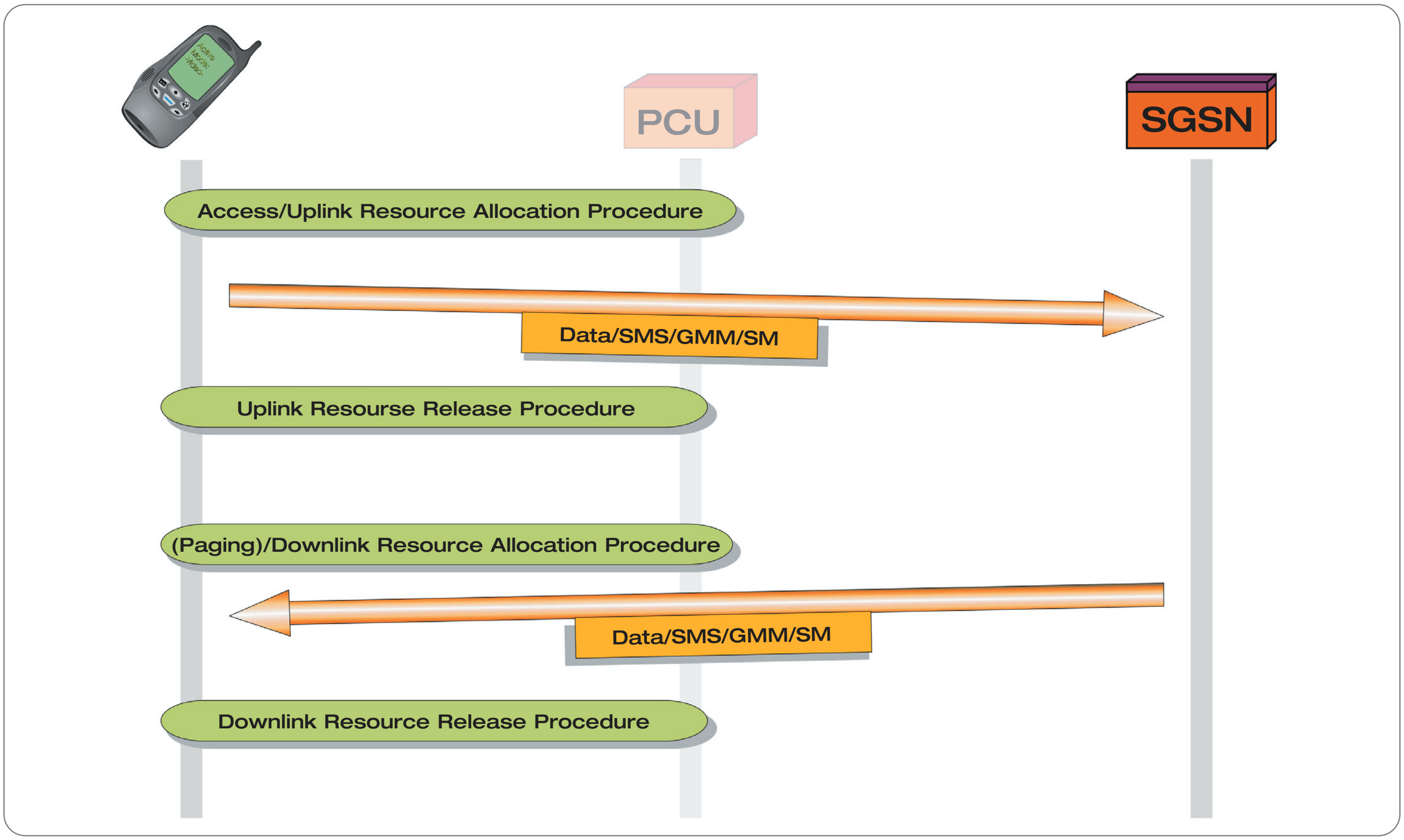


Figure 9. *For each data transfer and even for the transfer of signaling messages for GMM or SM, the establishment of a Temporary Block Flow (TBF) is required.*

If the K1205 is connected to both interfaces, (the Gb interface and the Abis interface), then users are usually surprised that in GPRS, the transfer of each GMM or SM message usually requires its own "channel establishment" and release procedure. In GPRS, we call this a Temporary Block Flow or TBF. Multiple data packets or GMM/SM messages may be transmitted within the same TBF, but that depends on the network setup and most importantly upon whether the mobile station or the PCU still have data to transmit to their peer in the respective output queue.

If the output queue is empty, the mobile station or the PCU will immediately release a TBF even when a PDP context still remains activated. Figure 9 illustrates this behavior in a generic manner.

The prior procedures are most important when it comes to GPRS operation. Let's take a closer look at some procedural problems and to obtain certain statistics with the K1205.

Typical GPRS Network Problems

Teething Diseases

Today, plenty of problems remain in GPRS networks that can be regarded as typical "teething diseases"; that is, problems that, while painful, are part of normal growth. Examples of this type of problem include conformance issues between the mobile stations and the network, and different interpretations of the specifications by different vendors.

Handling

Another source of problems is the erroneous setup and handling of GPRS enabled mobile stations by the end-user. For example, one can use the K1205 to find a good number of unsuccessful GPRS Attachments or PDP context activations that have resulted from these types of errors. But even so, a thorough investigation with the K1205 or extensive test sessions is required to exclude, for instance, systematic network failures. These two types of problems will certainly be sorted out in time, and hopefully they will be resolved before network load increases.

User Plane/Application

Another problem that GSM experts are beginning to see relates to specifics of mobile packet-switched data services. This type of problem involves delay, throughput or interworking problems between the mobile station (or the terminal equipment that is connected to the mobile station) on one hand, and network servers, which in turn may be internal or external to the GPRS network, on the other hand. Whether the server that possibly causes trouble is inside or outside the GPRS network does not concern users. For users, it will always be GPRS that isn't working properly as bearer for IP data. This type of problem is new to GSM experts because in speech-oriented GSM, most problems can be tracked down by call trace analysis on the signaling plane. Of course, there are also instances in GSM where the user plane requires special attention, but mostly it is sufficient to attest good or bad speech quality to an ongoing call.

Compare this to GPRS, which is dedicated to IP data services. In this new environment, problems may be caused by any protocol within or above the GPRS bearer, and many protocols are above the GPRS bearer. Usually, only TCP/IP is considered at this point, but actually the entire IP protocol stack needs to be taken into account. The K1205 allows technicians to decode the GPRS content of a specific message, and the entire IP content. This distinguishes the K1205 from other products on the market, most of which suffer from lacking decoding capabilities.

Packet Switched Data in the Mobile Environment

Another important issue that end users and technicians face in today's GPRS networks is a variable delay time, which affects ongoing data transmissions and causes TCP connections to drop. This variable delay time results from operating in a mobile environment, and is unavoidable, to a certain level. Unforeseeable delay times apply during cell updating and, even worse, during routing area updating while a data transfer is occurring. Later in this application note, we will provide an example that highlights the respective delay time during cell updating.

Short Time	From	5. Prot	5. MSG
10:50:40 AM	L1: 0/A	SWITCH ON	
10:54:11 AM	1:B (Rx):16	GMMSM681	ATRQ
10:54:11 AM	1:A (Rx):16	GMMSM681	ACRQ
10:54:11 AM	1:B (Rx):16	GMMSM681	ACRE
10:54:11 AM	1:A (Rx):16	GMMSM681	???
10:54:11 AM	1:B (Rx):16	GMMSM681	???
10:54:22 AM	1:B (Rx):16	GMMSM681	???
10:54:22 AM	1:A (Rx):16	GMMSM681	???

Without enabled deciphering no protocol testing and message interpretation is possible

The same message flow with an enabled Deciphering Function

Short Time	From	5. Prot	5. MSG
10:54:11 AM	1:B (Rx):16	GMMSM681	ATRQ
10:54:11 AM	1:A (Rx):16	GMMSM681	ACRQ
10:54:11 AM	1:B (Rx):16	GMMSM681	ACRE
10:54:11 AM	1:A (Rx):16	GMMSM681	ATAC
10:54:11 AM	1:B (Rx):16	GMMSM681	ACOM
10:54:22 AM	1:B (Rx):16	GMMSM681	APCR
10:54:22 AM	1:A (Rx):16	GMMSM681	APAC
10:54:22 AM	1:B (Rx):16	SNDCP670	DATA
10:54:22 AM	1:A (Rx):16	SNDCP670	DATA
10:54:45 AM	1:B (Rx):16	SNDCP670	DATA

Figure 10. *The deciphering function of the K1205 messages recorded on the Gb interface.*

How to Determine GPRS Network Problems with the K1205

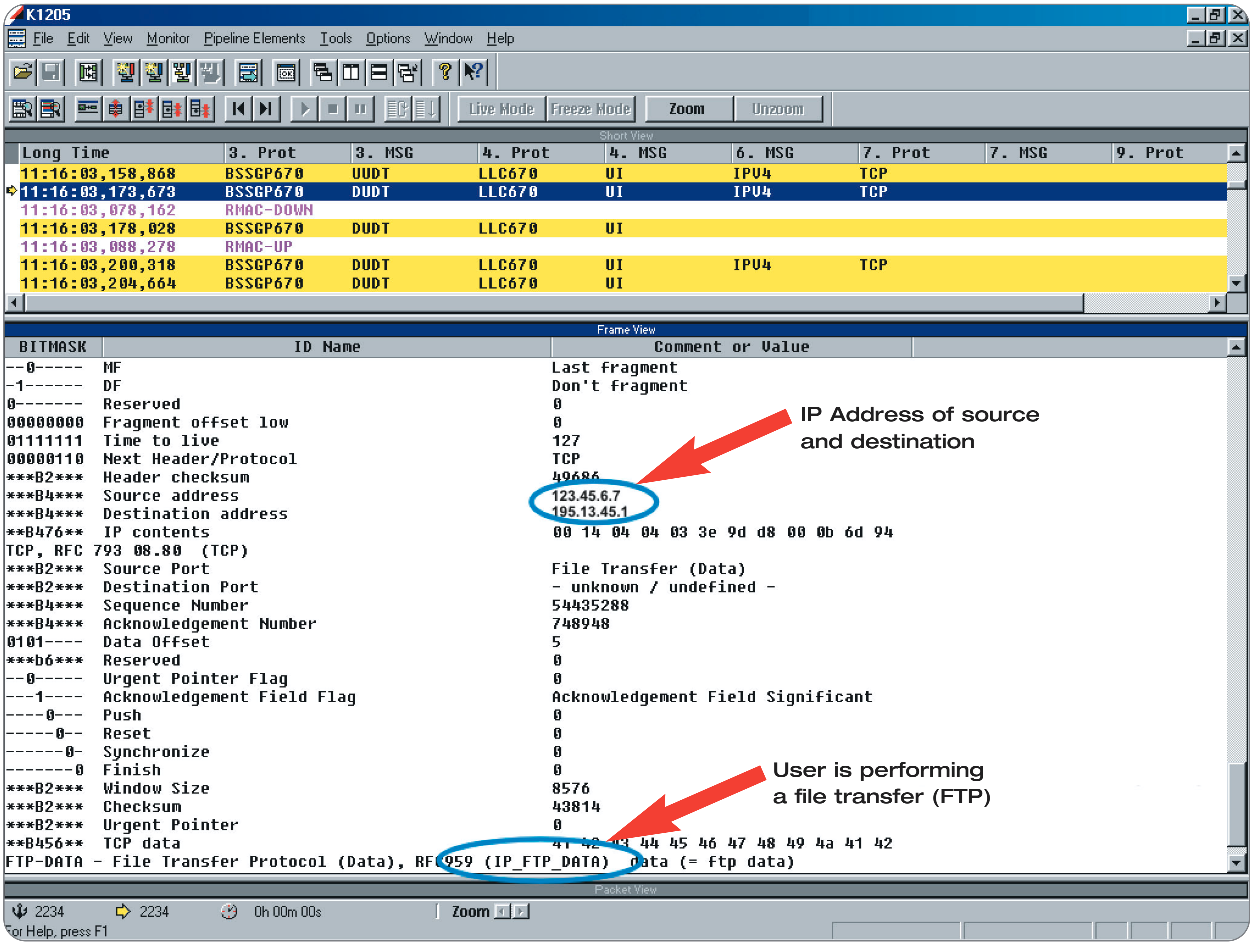
The Deciphering Function

A unique capability that distinguishes the K1205 from all other protocol analyzers arises from the specific operation of ciphering in GPRS, which differs essentially from ciphering operation in GSM:

- In GSM, ciphering is only applicable on the Um interface between the mobile station and the BTS. Therefore, in GSM the entire message flow on the terrestrial interfaces occurs deciphered and poses no problems for protocol observation.
- In GPRS, encryption is applied between the mobile station and the SGSN. As a consequence, and with enabled encryption, all data, short messages and signaling messages for GMM and SM are still protected on the terrestrial interfaces and prevent the technician from protocol analysis.

For both types of service, (circuit-switched GSM and packet-switched GPRS), ciphering is an important feature to prevent unauthorized tapping. For a ciphered data transmission, both GSM and GPRS usually require the previous authentication of the subscriber upon attachment. This authentication process is the calculation of the ciphering key Kc, which is never transmitted over the air interface.

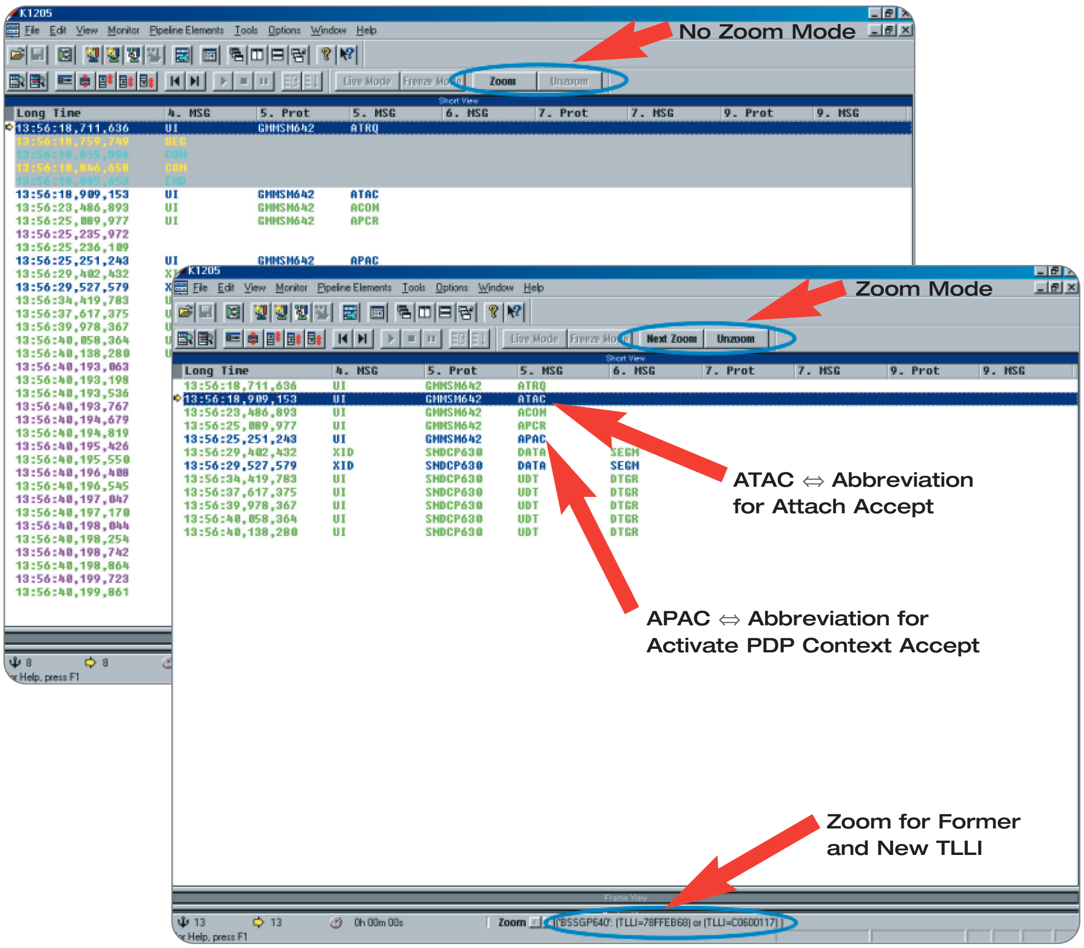
The successful use of the deciphering function requires that the K1205 be fed with the ciphering keys (GPRS-Kc) of the respective subscribers. Therefore, the K1205 needs to be connected to the Gr interface to tap the transmission of the authentication triplets (⇔ GPRS-Kc) from the HLR to the SGSN for a specific mobile station or manually input into the K1205.



▶ ***Figure 11.*** *The K1205 also decodes the entire TCP/IP protocol suite.*

Application Level Recording

The K1205 can be used for protocol analysis on all interfaces within and outside the GPRS network architecture. More importantly, the K1205 decodes messages up to the IP application layers. Not only can the GPRS-specific message flow be recorded, decoded and judged using the K1205, but the entire TCP/IP protocol suite can also be observed, *down to a single bit*. Accordingly, technicians can assign a given problem to the GPRS network, the mobile station, an external network server, or the application. Figure 11 illustrates an example of this decoding function (IP data), also recorded by the K1205 on the Gb interface.



▶ ***Figure 12.*** *The same message flow with and without Zoom function.*

The Zoom Function

In the laboratory, the traffic load is usually modest unless load tests are being performed. Therefore, follow-up of a single message flow is usually not a significant issue. However, the situation is entirely different when performing protocol analysis in the field. In operating networks several simultaneous transactions are likely to be ongoing, and it is very difficult and time consuming to track the signaling or data exchange of a given message flow. The Zoom function of the K1205 provides an excellent means to overcome these problems. Using this function, technicians can “zoom” into only one message flow or to filter out all other message flows

Figure 12 provides an illustration. The upper portion shows without the Zoom function, how different messages show a GPRS Attach procedure, a PDP context activation procedure, plus data transmission are mixed with other message flows. As shown, the sequential follow-up of the various messages is a rather tedious task.

The lower part of Figure 12 illustrates the advantages of the Zoom function of the K1205. Only the message flow of a single subscriber is presented after applying the Zoom function on the BSSGP message part. The Zoom function precisely filters out all messages that are not related to a certain TLLI (⇔ subscriber).

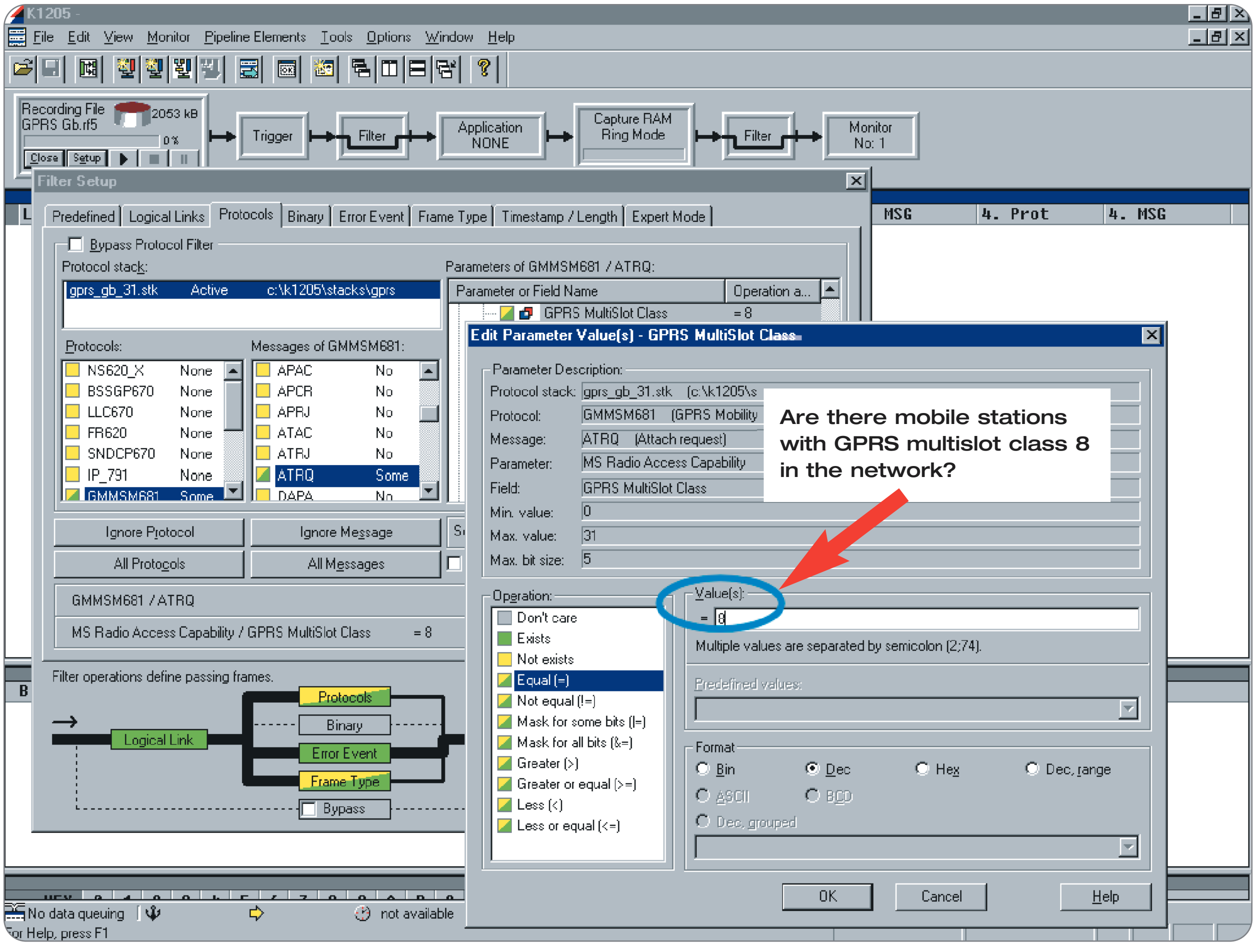
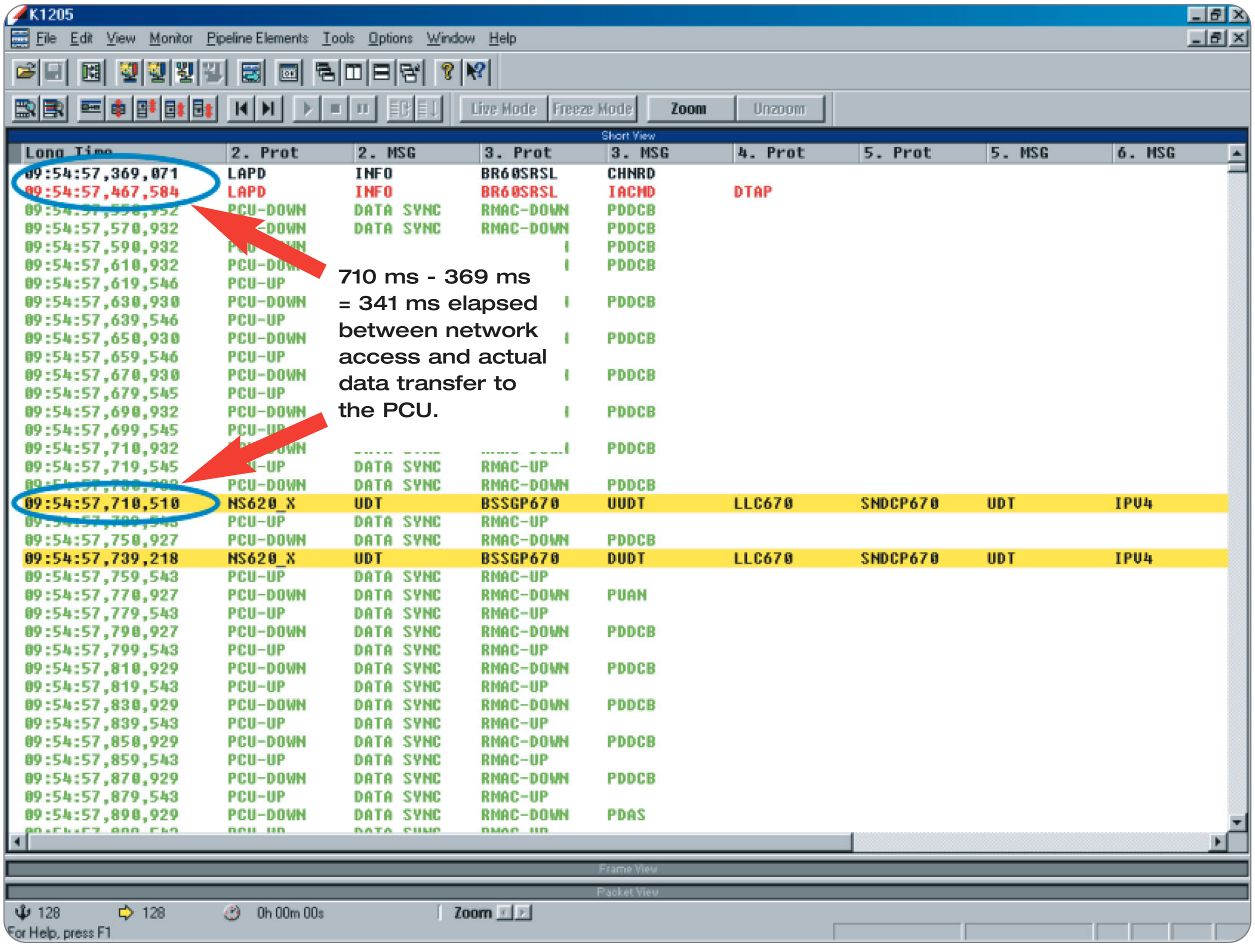


Figure 13. *Using the filter function of the K1205.*

The Filter Function

Different tools are required within a protocol analyzer to most efficiently identify an error or to obtain specific information. In addition to the Zoom function, the K1205 also offers filter functions that may suit other requirements better than the Zoom function. The filter functions of the K1205 have become more and more sophisticated over the years, and they were also adopted for the GPRS protocol suite. Figure 13 illustrates an example. In this case, we were asked to find out whether there are already subscribers in our network who are using mobile stations with multislot class 8. By means of the K1205 filter function, it is very easy to retrieve this information. After applying this filter, only GPRS attachments of mobile stations with multislot class 8 are presented on the monitor.

This is just one example of the various problems that the filter functions of the K1205 can solve.



▶ ***Figure 14.*** *Delay measurements with the K1205.*

Delay Measurements

When it comes to quality of service in packet-switched networks, an essential consideration is the involved delay times. The K1205 is the preferred tool for measuring delay times within the GPRS network. More importantly, the K1205 makes it possible not only to measure roundtrip delays, but to obtain a detailed view of which part of the network or which part of a procedure is causing the delay. The following two cases highlight typical examples.

Time Delay during Network Access and Resource Allocation

Part of the overall delay in GPRS is due to the time required for access and transfer on the Um interface. In that respect, access refers either to paging and resource allocation to the mobile station in the case of downlink data transfer, or to network access and resource allocation in the case of uplink data transfer.

To judge the delay times involved, the K1205 should be connected to the Abis and Gb interfaces. Then, to judge at least the important delay time between the mobile station and the SGSN, simply read the time-stamps between the Channel Required message (CHNRD) on the Abis interface, and the transfer of the Uplink Unitdata PDU (UUDT) on the Gb interface.

Figure 14 illustrates the previously mentioned example. Obviously, this technique also works on all other interfaces, if applied between the Abis and Gi interface.

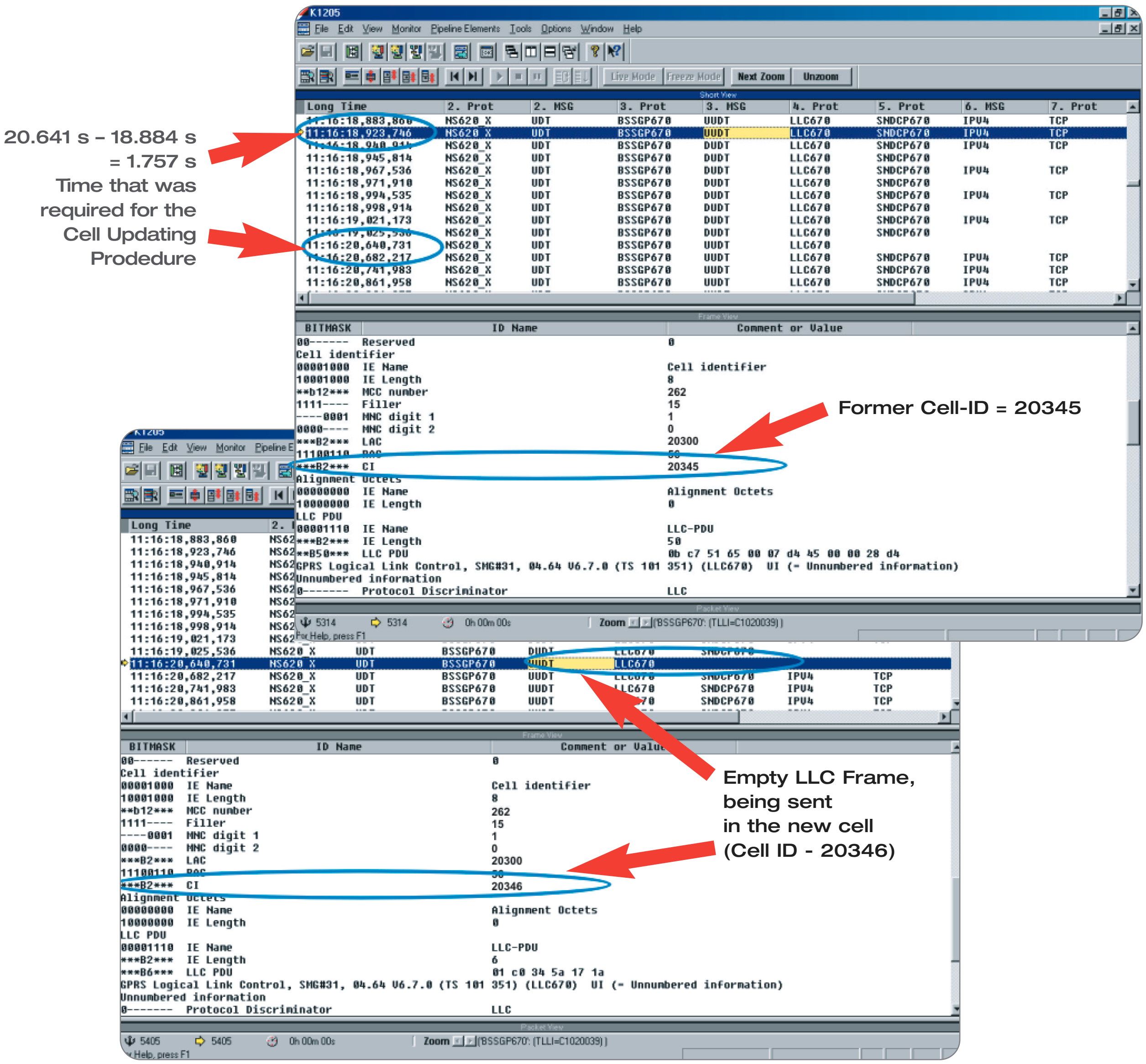
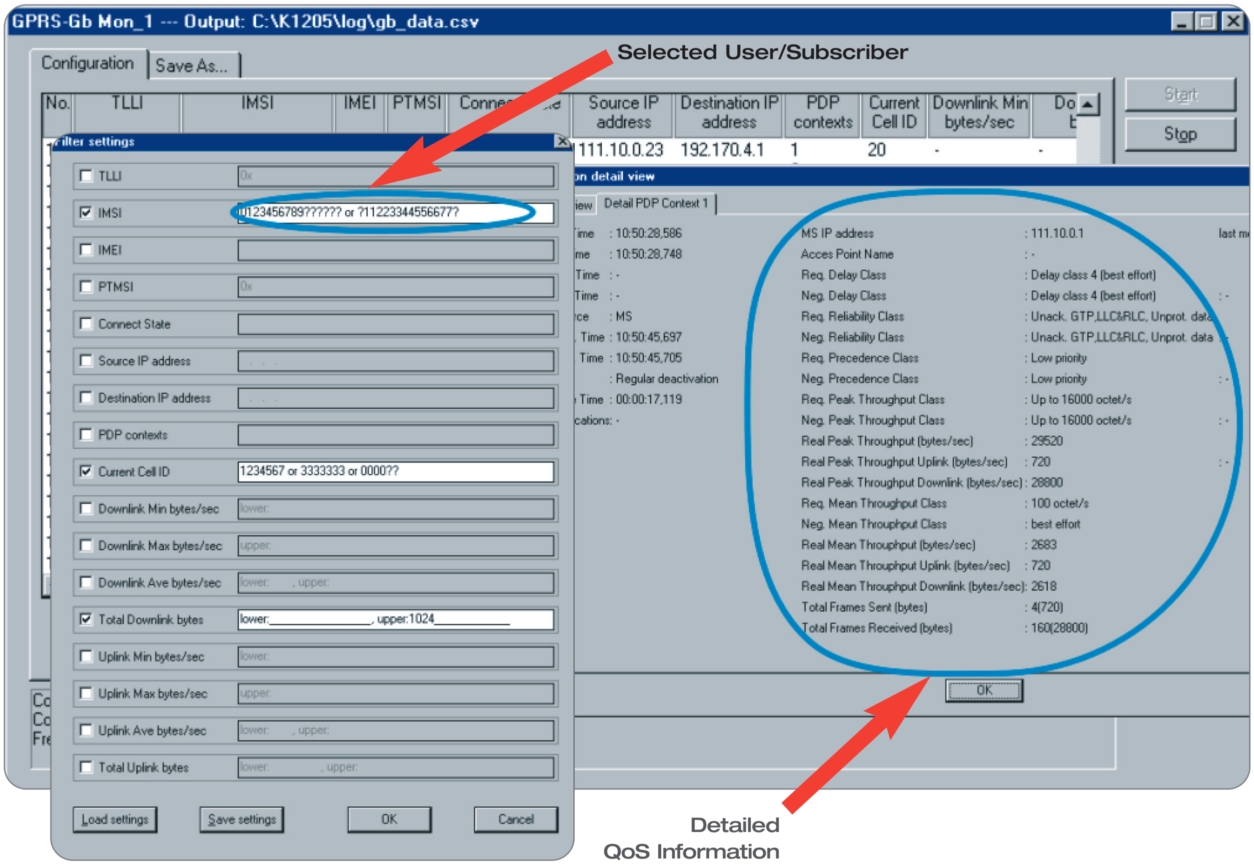


Figure 15. *Time Delay due to Cell Updating (with Zoom function enabled).*

Time Delay during Cell Updating:

The cell updating procedure, which has been introduced earlier, always occurs upon cell reselection in GMM READY State, most likely when a moving mobile station and the network are exchanging data. A cell reselection causes a certain delay time, but how much on average? There is no better means than to use a protocol analyzer like the K1205 to obtain this information. Figure 15 shows an example.



▶ ***Figure 16.*** *Statistical QoS measurements with the K1205.*

Automated GPRS Statistics with the K1205

We have presented several examples on protocol analysis with the K1205. Generally, these examples required the manual interpretation of one message flow or even single messages or data blocks. The K1205 features capabilities that go far beyond this. With its statistics functions, the K1205 provides large amounts of statistical information about network performance and error rates. These statistics are produced by a tool that is independent of the vendor's equipment. The following examples illustrate this additional capability of the K1205.

GPRS Gb Monitor

In the lab and in the field, it is frequently necessary to trace all data flows of a single or more PDP contexts. It is possible to compare the quality of service provided by certain parts of the equipment such as different servers, different vendors or different mobile stations, or different software releases. The K1205 is an outstanding tool for statistical measurements. Figure 16 illustrates an example where the K1205 provided information on the status of various GPRS session activities and on the performance of the related data transfers that the users experienced.

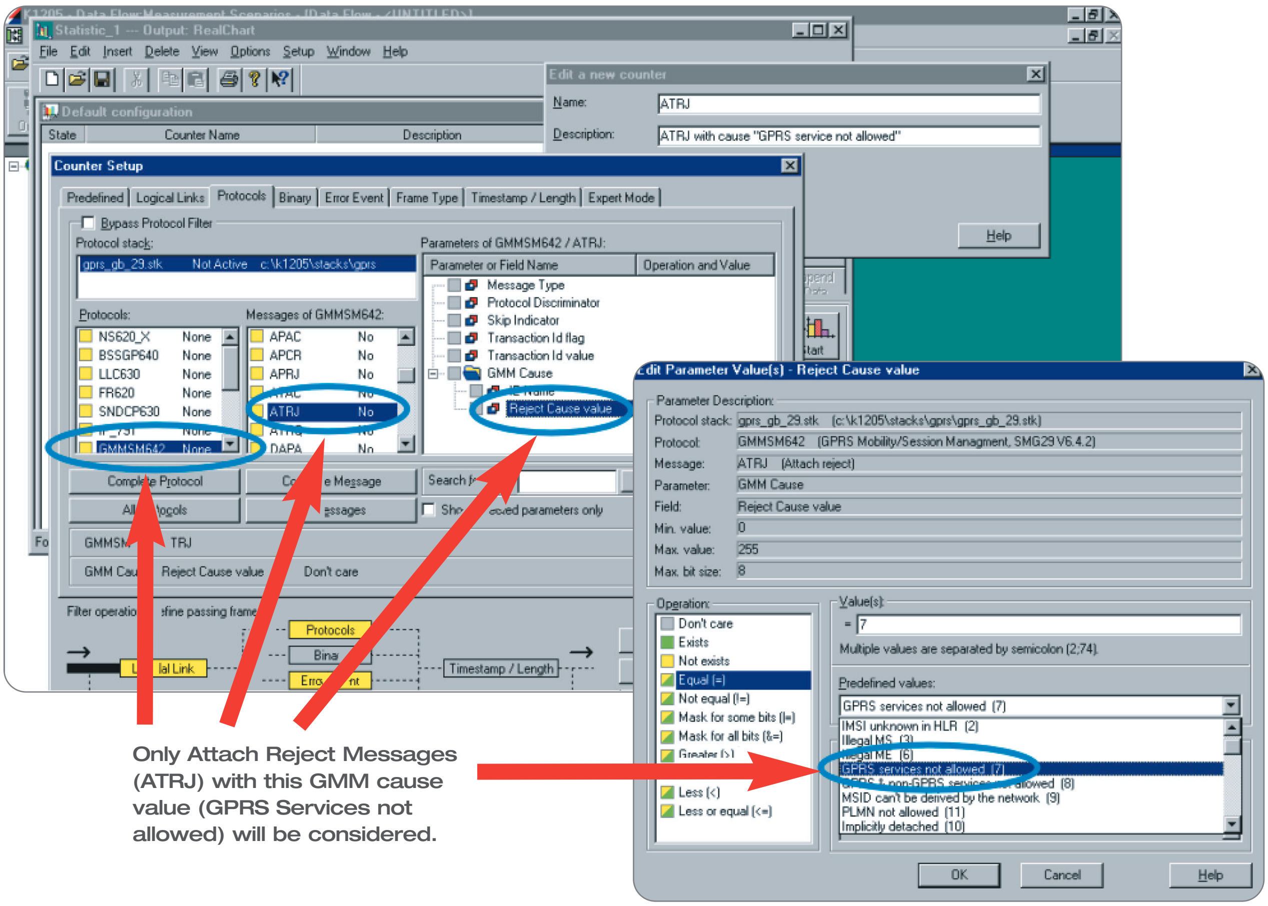


Figure 17. Statistical GMM measurements with the K1205.

Statistic Application

An often requested capability is the provision for counting messages, best possible even in connection with their parameters. This can easily be executed using the Statistic application of the K1205. Figure 17 illustrates another example of statistical measurements. In this case, it was important to determine the number of unsuccessful GPRS attachments (Attach Reject ⇔ ATRJ) due to a specific GMM cause ("GPRS Services not allowed"). By means of the K1205 statistics functions, recording file and error analysis becomes an easier task. Technicians can first obtain an overview of the situation in a given part of the network, and based on the statistics, can delve further into the recording file for a closer look at specific messages to track down the problem.

Summary

While the examples and procedures illustrated in this note only provide a small window of the wide scope of today's and tomorrow's GPRS network problems, the protocol analyzer will remain the tool of choice that guides technicians to the source of a problem. The ideas and guidelines that have been presented should enable you to use your K1205 efficiently.

Tektronix strives to provide you the best possible communications test equipment and service possible, today and in the future with add-on applications for the K1205 that meet your specific needs. If you encounter a situation or a failure during your daily work that could be more easily resolved by an application that is not yet supported by the K1205, please contact us via e-mail at: mpt.hotline@tektronix.com.

Questions? Please contact us

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Abbreviation List

BSC	Base Station Controller
BSS	Base Station Subsystem
BTS	Base Transceiver Station
GGSN	Gateway GPRS Support Node
GMM	GPRS Mobility Management
GPRS	General Packet Radio Service
HLR	Home Location Register
IP	Internet Protocol
NOM	Network Operation Mode
PCU	Packet Control Unit
PDP	Packet Data Protocol
QoS	Quality of Service
SGSN	Serving GPRS Support Node
SM	Session Management
SMS	Short Message Service
TBF	Temporary Block Flow
TCP	Transmission Control Protocol
TLLI	Temporary Logical Link Identifier

References

[1] GPRS – Signaling & Protocol Analysis / Vol 1 and 2 / ISBN 393627301 – 4

[2] GSM 03.60 / General Packet Radio Service – Service Description; Stage 2

[3] GSM 04.08 / Mobile radio interface layer 3 specification

[4] GSM 08.18 / General Packet Radio Service (GPRS);
Base Station System (BSS) – Serving GPRS Support Node (SGSN);
BSS GPRS Protocol (BSSGP)

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