2.5G/3G Core Network Testing with G35: The Foundation of Packet Switched Connectivity and Reliable IMS Services

Abstract

With the advent of broadband mobile networks like UMTS and service platforms like IMS, the interaction between them both is leading to entirely new test challenges. Ensuring superior end-user Quality of Experience (QoE) is adequately supported by the underlying UMTS core and access network infrastructure is just one of these new test challenges being faced by Network Equipment Manufacturers and service providers alike.

This whitepaper introduces some of the key procedures needed to establish sessions in the packet-switched 2.5G/3G core network, as well as at the service layer. In this document, we will use IMS sessions as specific example. Related test challenges and how they can be addressed by using Tektronix’ G35 protocol test platform are then highlighted. Finally, the impact of new services such as Push-to-Talk over Cellular (PoC) and Multimedia Broadcast and Multicast Services (MBMS) on the 2.5G/3G core network infrastructure are explained.

Introduction

The adoption of recently standardized UMTS R5 and R6 features like HSDPA and HSUPA is transforming mobile networks into real broadband communication systems. Declining voice revenues require carriers to seek out alternative sources of revenues by developing new services for their customers.

The advent of IEEE 802.16e, commonly known as “Mobile WiMAX”, as alternative mobile broadband technology will reinforce this trend. With this new technology, competing service providers appear on the horizon, thereby enabling more and more end users to adopt and incorporate IP-based services into their daily lives.

IMS and other Packet Data platforms give service providers the ability to deploy multiple services with higher QoE at reduced overall cost. Applications as diverse as Ringtone Downloads, Text Messaging, E-Mail, Picture Messaging and Information Services have shown to be equally popular. Migrating these type of services towards a common platform in order to optimize Operating Expenses related costs will be a strong driver for mobile (and fixed) operators to adopt IMS-based systems.

Primary and Secondary PDP Context

The one thing all these different applications have in common is that a certain Access Point is needed for their availability. Access Points are IP routers that provide the connection between the Mobile Station (MS) and the selected application. The MS must know the Access Point Name (APN) in order to contact the desired Access Point via the GPRS subsystem. This is done through a PDP context activation procedure as depicted in Figure 1.

The MS sends an *Activate PDP Context Request* message that consists of PDP Type, PDP Address, Access Point Name, Quality of Service (QoS) Requested and Protocol Configuration Options to the SGSN. The SGSN uses the APN, which has the format of a 'Fully Qualified Domain Name', to select a reference point (the GGSN) to the external network. The APN is a logical name referring to the external Packet Data Network (PDN) that the subscriber wishes to connect to. The Domain Name Server function resolves the logical APN name to an IP address. This function is standard Internet functionality according to RFC 1034 [1]. As a result, the SGSN finds a GGSN that is connected to the desired external network. In the next step, the SGSN initiates the *Create PDP Context* Procedure to this GGSN.

QoS Requested indicates the desired QoS profile. Protocol Configuration Options may be used to request optional PDP parameters from the GGSN. Those Protocol Configuration Options are then sent transparently through the SGSN.

After sending the Activate PDP Context Request, a timer will be started in the MS while waiting for the *Activate PDP Context Accept* or *Reject* message.

The SGSN validates the Activate PDP Context Request. The SGSN rejects the PDP context activation request if no GGSN address can be derived, if the APN cannot be resolved or if the SGSN has determined that the Activate PDP Context Request is not valid.

If the PDP context activation procedure is successful, a user plane tunnel between the MS and an external Packet Data Network (PDP) will be established. It is important to note that this is a user plane tunnel from GPRS perspective only; from the viewpoint of the external PDN, it would be possible to also carry control plane information such as SIP messages.

As stated above, the Access Point is the first contact point for the external service platform. Examples of such services platforms are:

- Short Message Service Center (SMSC)
- Multimedia Messaging Service Center (MMSC)
- Wireless Application Protocol (WAP)
- IP Multimedia Subsystem (IMS)
- Internet

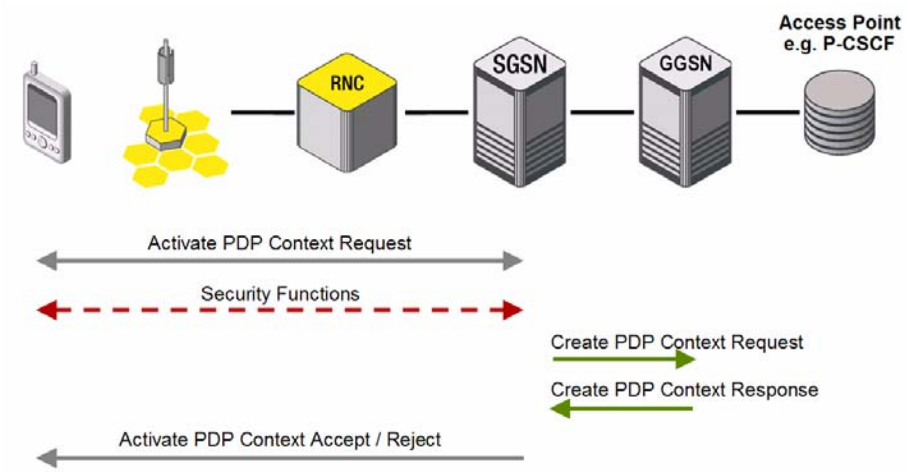

Figure 1. PDP Context Activation Procedure (MS initiated)

One GGSN may offer different services that can be accessed through different APNs. From the viewpoint of the external PDN, the usage of primary and secondary PDP contexts must be distinguished (see Figure 2). A primary PDP context will always be established for the first connection between an MS and a specific APN. Up to 10 secondary PDP contexts may then be established if further connections with the same APN are needed. Usually, every IMS media stream will be routed independently over a separate tunnel. This is necessary because the GPRS charging function in Release 5 is not able to generate multiple charging records for one data stream. Additionally, different IMS user plane sessions may have different QoS requirements.

Thus, PDP contexts can be categorized as following:

1. Primary PDP contexts: They provide connections to different APNs. The SGSN assigns a unique IP address to the MS for each primary PDP context.

2. Secondary PDP contexts: They provide connections to the same APN, but with different QoS. A secondary PDP context is always associated with one primary PDP context. Both IP addresses and Access Points are re-used from the primary PDP context.

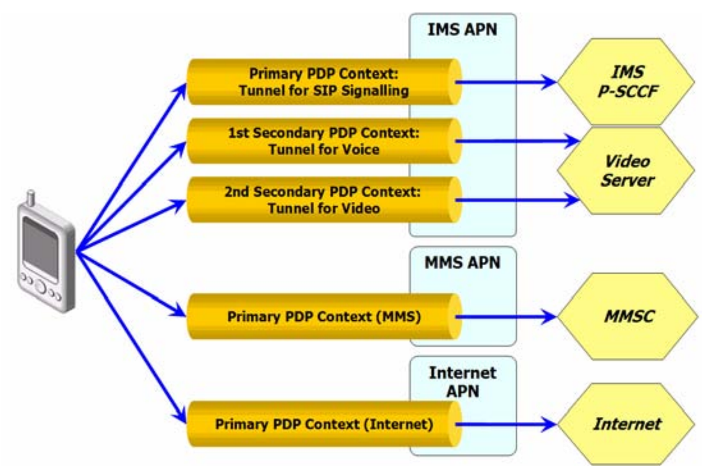

Figure 2. PDP Context Types

The QoS of any active primary or secondary PDP context can be modified by the MS or network using the *PDP Context Modification* procedure [2]. Figure 3 depicts the negotiated QoS parameters simulated by the G35 protocol tester. For detailed information concerning QoS parameters used in UMTS networks, refer to [3; chapter 6.4.3: “UMTS Bearer Service Attributes”].

The maximum number of supported PDP contexts depends on the MS’s capabilities. Typical test mobiles support up to six PDP contexts. SGSN/GGSN nodes can support up to eleven PDP contexts per MS. For thorough stress testing, the G35 simulates up to 6 million mobile subscribers whereas every simulated MS may have up to 11 PDP contexts activated. With a total capacity of more than 60 million simultaneous GPRS tunnels, the G35 can simulate mobility scenarios and subscriber load ranging from a small rural area up to the largest metropolitan city.

Frame View

BITMASK	ID Name	Comment or Value
0000----	Spare	0
Quality of Service		
00001011	IE Length	11
-----100	Reliability class	Unack. GTP,LLC&RLC, Prot. data
--011---	Delay class	Delay class 3
00------	Spare	0
-----010	Precedence class	Normal priority
----0---	Spare	0
0001----	Peak throughput	Up to 1000 octet/s
---11111	Mean throughput	best effort
000-----	Spare	0
-----001	Delivery of erroneous SDUs	No detect ('-')
---01---	Delivery order	With delivery order ('yes')
001-----	Traffic class	Conversational class
00001101	Maximum SDU size	13
01100100	Max bit rate for uplink	100
10000000	Max bit rate for downlink	128
----0001	SDU error ratio	1*10-2
0001----	Residual Bit Error Rate	5*10-2
------01	Traffic handling priority	Priority level 1
000010--	Transfer delay	2
00110010	Guarntd bit rate uplink	50
01100000	Guarntd bit rate downlink	96

Figure 3. Quality of Service IE (Screenshot from G35 Protocol Simulator)

Traffic Flow Template (TFT) and Protocol Configuration Options (PCO)

Since a PDP address (e.g. IP address) is common for the primary and for all associated secondary PDP contexts, the questions arises as to how user plane content (SIP signaling, voice, video, etc.) can be mapped to the correct GPRS tunnel (see Figure 2). As the IP Address alone is not an adequate indicator, another information element needs to be exchanged during the *Secondary PDP Context Activation* procedure, the *Traffic Flow Template* (TFT) [2; chapter 9.2.2.1.1]. The TFT is provided by the MS, stored in the GGSN and is examined when downlink user plane data needs to be delivered to the MS. The TFT can be modified or deleted by using the MS-initiated *PDP Context Modification* procedure. By means of the MS initiated *PDP Context Modification* procedure, a TFT may also be assigned to a primary PDP context [2; chapter 9.2.3.3].

The TFT Information Element is an array of packet filters and is used by the GGSN to inject IP packets (SIP, RTP, MPEG, etc.) into the correct GPRS tunnel. Each packet filter has a variable length and consists of the following elements:

- packet filter identifier
- packet filter evaluation precedence
- the length of packet filter content
- the packet filter content itself

The *packet filter identifier* is used to identify each packet filter inside the TFT array.

The *packet filter evaluation precedence* specifies the precedence class among all packet filters associated with a given PDP address (IP address). Signaling may have higher precedence than user plane, and streaming services a higher precedence than background services.

The size of the *packet filter content field* itself is variable and contains exactly one of the following filter types:

- IPv4 source address
- IPv6 source address
- Next header type
- Single destination port
- Destination port range
- Single source port
- Source port range
- IPSec Security parameter index
- Traffic Class / Type of Service
- Flow Label

More information about usage and structure of the TFT Information Element can be found in [2; chapter 15.3] and [4; chapter 10.5.6.12: “Traffic Flow Template”].

The relationship between PDP contexts, TFTs and packet filters is depicted in Figure 4.

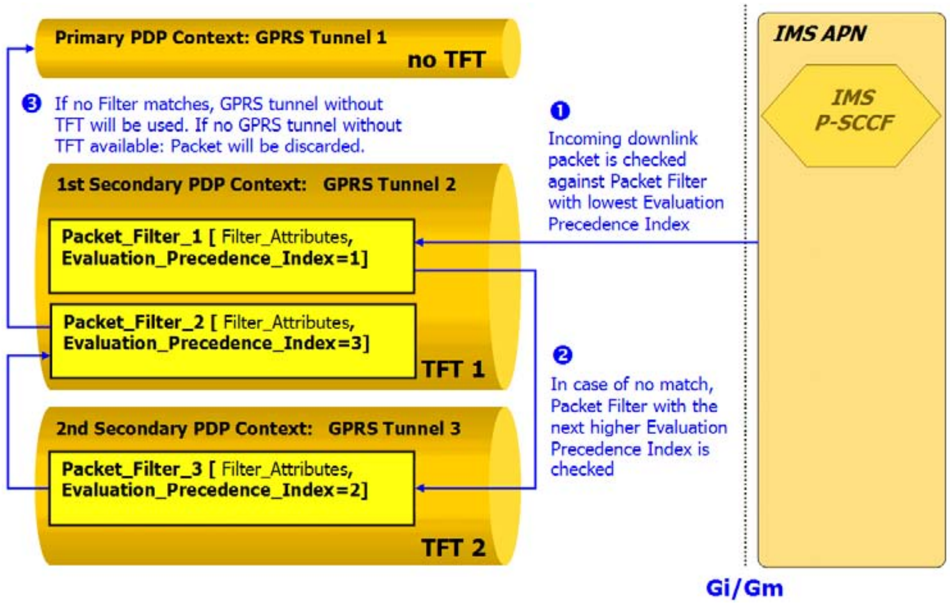

Figure 4. PDP contexts, TFTs and Packet Filters

The Evaluation Precedence Index specifies the order in which packet filters are examined. The Evaluation Precedence Index has a unique value for all PDP contexts. If the data packet matches a Packet Filter, it is routed through the GPRS tunnel of the associated context. Otherwise, the next Packet Filter will be analyzed. At most, one PDP context (typically the primary context) for each PDP Address is allowed to have no assigned TFT. This PDP context is the default routing direction for all downlink packets that don't match any assigned Packet Filter. If all PDP contexts have an assigned TFT, then all non-matching downlink packets will be discarded by the GGSN.

As discussed previously in this document, one function of the PDP Context Activation procedure is to dynamically assign an IP address to the MS (Source IP Address). However, the MS also needs to know the Destination IP address of the corresponding DNS Server before it is able to access any external service. In case of IMS services, the MS needs to know the IP address of the entry point to the IMS, the Proxy-Call Session Control Function (P-CSCF). A convenient way of specifying this destination IP address lies in using the PCO Information Element (PCO IE).

The structure of the PCO IE is defined in [4; chapter 10.5.6.3]. It is possible to embed complete messages into the PDP Context Activation procedure by using the PCO IE, then exchanging them transparently between MS and GGSN. The following protocols are currently supported (3GPP R6):

- Link Control Protocol (LCP)
- Password Authentication Protocol (PAP)
- Challenge Handshake Authentication Protocol (CHAP)
- PPP (Point-to-Point Protocol) IP Configuration Protocol (IPCP)

The DNS / P-CSCF discovery procedure works in the following way (see Figure 5):

1. The MS requests the DNS / P-CSCF address via IPCP *Configure-request* message that is embedded into the PCO Information Element.

2. The GGSN responds with the DNS / P-CSCF server address in the DNS / P-CSCF address field of the PCO Information Element (IPCP *Configure ack* message).

3. The MS sends the first message over the GPRS tunnel to an external network such as *SIP REGISTER* or *SIP INVITE*.

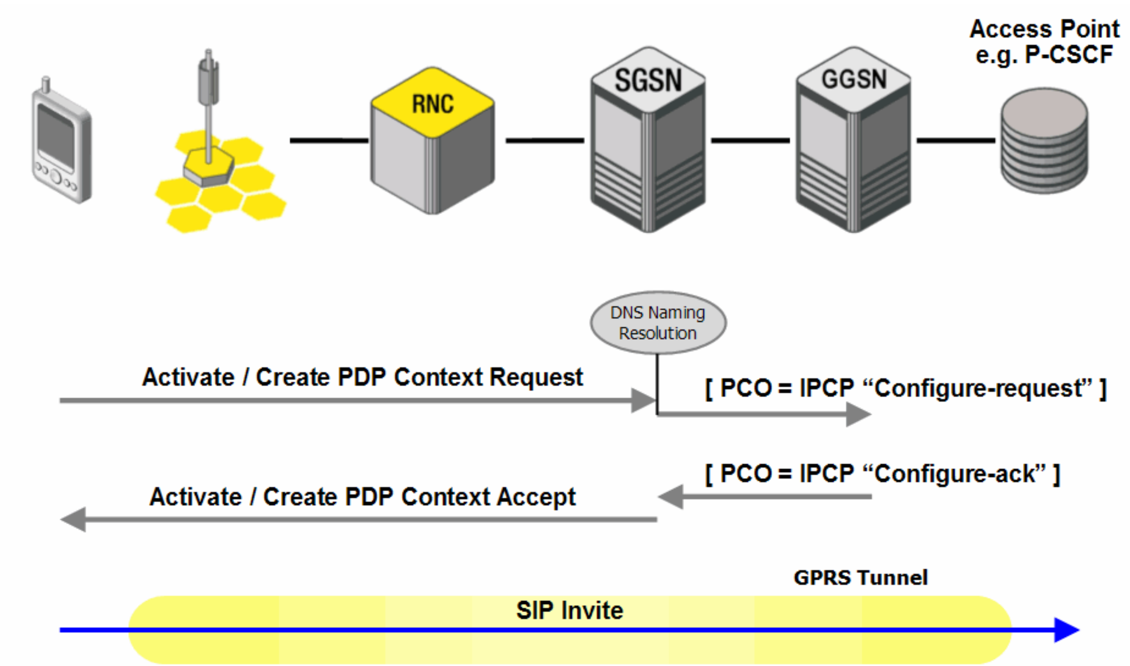

Figure 5. P-CSCF Discovery Procedure

This mechanism allows the configuration of Session Initiation Protocol (SIP) proxy addresses under the APN to be used for IMS or Voice over IP (VoIP). The SIP proxy addresses are then returned in the PCO Information Element, allowing the handset to use IMS or other similar applications.

The G35 offers flexible templates for user-defined TFT and PCO configuration. These features, in combination with the ability to simulate millions of subscribers, allow real-world traffic model to be shaped. For an assessment of current and future network conditions, the G35 is able to simulate complex load scenarios. Mobile users are simulated in a way that all relevant parameters are taken into consideration. This helps to ensure that the transition from the evaluation lab to the live network is smooth and free of unexpected performance problems.

Quality of Service Negotiation

Another important aspect for the proper operation of the GPRS subsystem – in addition to a reliable APN resolution and mixture of different PDP context types – is the correlation of QoS parameters between the GPRS domain (see Figure 3) and the external PDN.

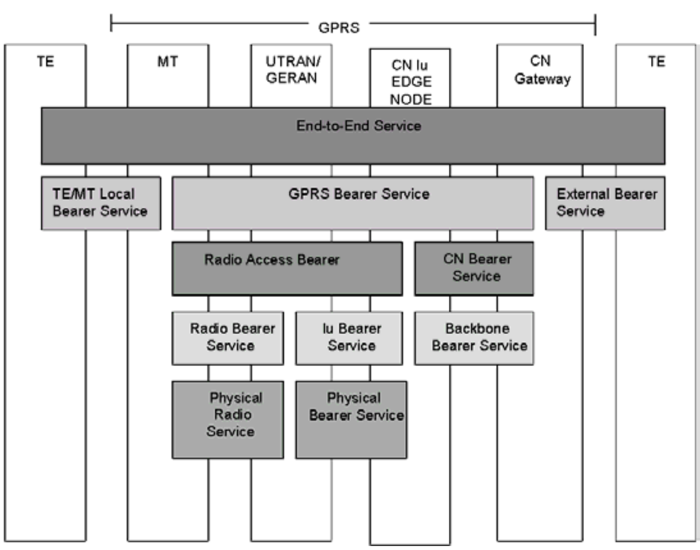

Figure 6. End-to-End QoS Architecture [6]

This aspect and its related pitfalls are discussed in this section based on the example of using an IMS network as external PDN.

The high-level UMTS service and system aspect is depicted in Figure 6. The End-to-End Service between the terminals and the CN Bearer Service between SGSN and GGSN are the most relevant for the subject discussed in this section. At first glance, both services are independent from each other, as the related service layers start and terminate at different reference points. Obviously, the end-user experience can never be better than the quality granted by the GPRS core network.

The relationship between GPRS Core (CN Bearer) and IMS (End-to-End) QoS parameters is illustrated in Figure 7, which also highlights the dependencies between GPRS and IMS messages during the call establishment procedure.

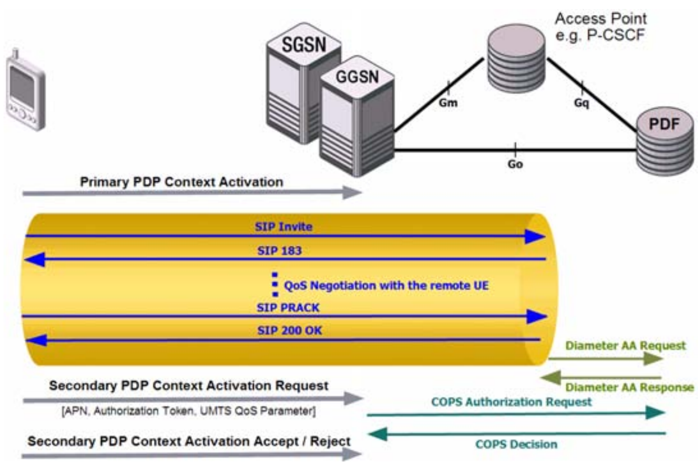

Figure 7. IMS Bearer Authorization over GPRS

When User A wants to establish a session with User B (for example, for a chess game), the calling MS generates a *SIP INVITE* message and sends it via the Gm reference point to the Proxy-CSCF. The Proxy-CSCF processes the request; inserts an Authentication Token; and forwards the *SIP INVITE* message to User B. User B generates a *183 Session Progress* message as a response. It then traverses back to User A. It takes a few more round trips to finalize the session establishment. User A sends the final offer with a *PRACK* message and suggests one codec per accepted media which needs to be confirmed from the other side by a *200 OK*. The Proxy CSCF stores the media-related information and delivers the Authentication Token to User A. Next, the Proxy-CSCF informs the Policy Decision Function (PDF) over the Gq reference point about the activated session (*AA Request, AA Response*). The *AA Request* message contains, among other elements, information about the application, information about the media stream and the resource reservation policy. This procedure completes the media negotiation.

Once the session is successfully established, User A initiates a *Secondary PDP Context Activation* procedure (Parameter: APN, Authorization Token, UMTS QoS). After receiving the *Secondary PDP Context Request* message, the GGSN asks for authorization information from the PDF. To do this, the GGSN sends a COPS Authorization Request message over the Gq reference point. The PDF compares the received binding information with the stored authorization information and returns an authorization decision (*COPS Decision*). The PDF communicates details of the media authorization in the decision to the GGSN if the binding information is validated as correct. These details contain IP QoS parameters and packet classifiers related to the PDP context.

The GGSN maps the authorized IP QoS parameters to the authorized UMTS QoS parameters. Finally, the GGSN compares the <u>authorized</u> UMTS QoS parameters against the <u>requested</u> QoS parameters from the Secondary PDP Context Request. The PDP Context Activation will be accepted if the UMTS QoS parameters from the Secondary PDP Context Request lie within the boundaries authorized by the PDF. [6]

Besides this procedure, the SGSN may restrict the requested QoS attributes based on its capabilities and the current load. It must also restrict requested QoS attributes according to the subscribed QoS profile, which represents the maximum QoS per PDP context to the associated APN. [2]

But what are the flaws in this procedure? The determination of the End-To-End QoS attributes takes place <u>before</u> there is any indication if the underlying GPRS transport network can fulfil these requirements. The user will experience call drops if the GPRS domain is poorly dimensioned.

Due to this relatively complex procedure involving several nodes and reference points, the rejection of the session establishment doesn't occur immediately, but only after a certain delay. This will likely cause end user frustration. It would be better if the end user were informed at the beginning of the SIP media negotiation if a certain service is currently not available.

There is no real negotiation of UMTS QoS attributes between SGSN/GGSN and MS. Only SGSN/GGSN can accept, downgrade or reject PDP context activation. The MS is not involved in determining the extent to which the QoS attributes are downgraded.

The GPRS Core (CN Bearer) and IMS (End-To-End) network can belong to different operators or service providers. In other words, the IMS service provider cannot directly influence the performance and robustness of the GPRS network. As a result, the introduction of new services may fail because they aren't accepted by end-users. This is critical, especially for business applications.

GPRS domain verification with G35

The G35 GPRS Functional and Load Test Platform from Tektronix is a scalable multi-technology system. In the basic configuration, a portable device is equipped with only one simulation board. For complex load scenarios, a rack system can be equipped with up to 13 simulation boards. Different hardware interfaces can be combined into one cabinet, for example E1 boards for simulation of 2.5G Access Networks (GERAN), ATM boards for simulation of UMTS Radio Access Networks (UTRAN), and Ethernet boards simulating external PDNs.

The G35, with its unmatched flexibility, offers simulation and emulation capabilities for a large number of network elements. It is therefore possible to test the GPRS subsystem under various conditions. A typical use case is depicted in Figure 8.

The G35 simulates the Radio Access Network including a certain number of mobile subscribers. These subscribers might be distributed over 60 virtual radio cells. But in the simplest scenario, all simulated subscribers are located in the same cell.

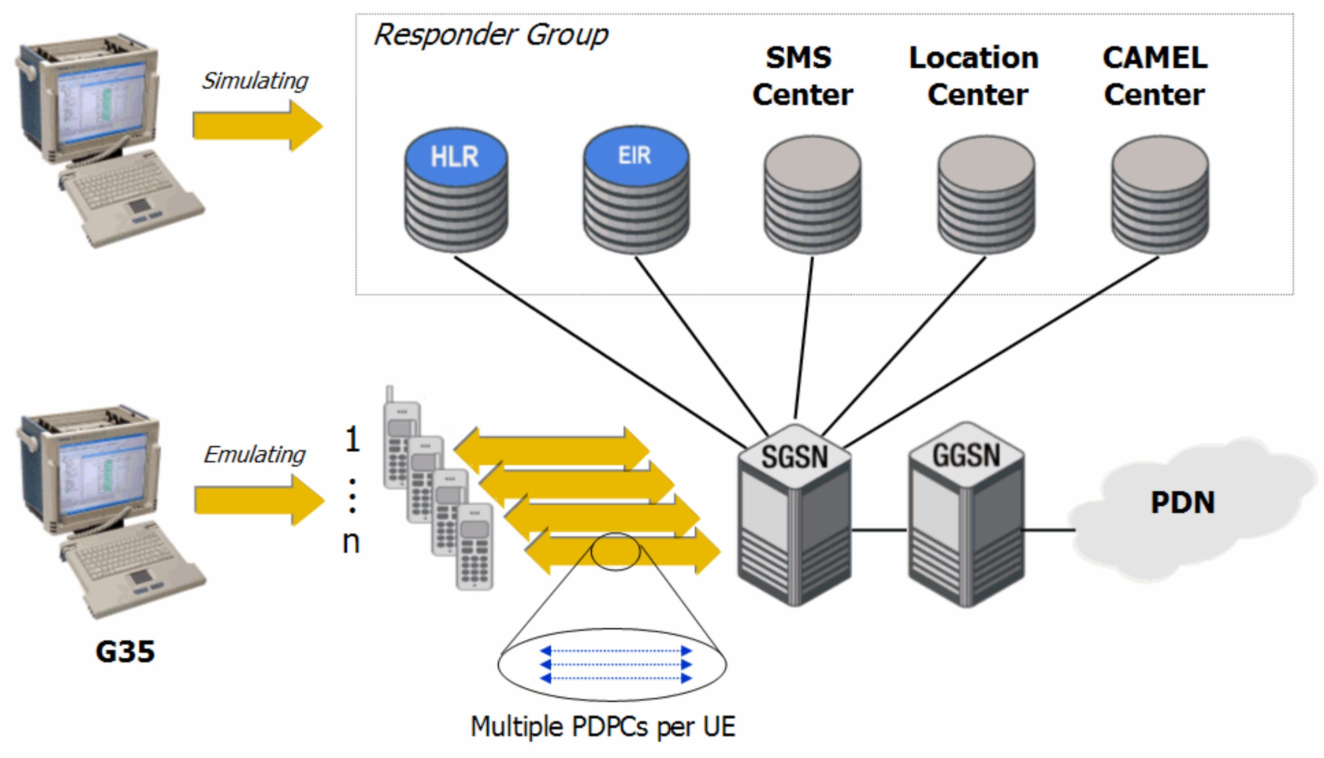

Figure 8. Typical topology for GPRS load testing

Typical parameters for the cell setup are technology (2G, 3G), Routing Area Code (RAC), Mobile Country Code (MCC) and Mobile Network Code (MNC). This approach allows the user to cluster the subscribers accordingly and to simulate various mobility behaviours, such as:

- Moving train: All subscribers are attached to a 3G cell. After a certain period of time, 3G-coverage is lost. All subscribers need to perform an Intersystem Change and attach to a 2G network cell.
- Crossing the border: The subscribers switch cells with different RAC, MNC or MCC. Routing areas update procedures need to be performed.
- Urban area: Subscribers are more or less equally distributed over several cells and switch to other cells in a pseudo-random fashion. Subscribers need to perform cell reselection or cell change procedures.

All mobility scenarios will be triggered with the same command. Depending on cell configuration, the G35 will automatically detect and initiate the relevant Mobility Management procedures.

Depending on the use case it is also possible to simulate other network elements like Equipment Information Register (EIR), CAMEL Center, SMS Center, Location Center, Home Location Register (HLR), etc. Many operators have a considerable amount of prepaid users. As a result, for a mixed configuration of pre-paid and after-paid users, it is also necessary to simulate the relevant transactions over the Ge-Interface between SGSN and CAMEL Center.

Another typical test scenario is functional testing combined with background load. This is especially important during the introduction of new services (cf. next section). A large number of simulated subscribers perform standard GPRS procedures, like ATTACH, PDP Context Activation / Deactivation, IP Transfer and DETACH. These subscribers constitute the group generating the background load. Another smaller group comprises a limited number of subscribers (e.g. 1 to 20) and injects procedures related to new (IMS, for example) services into the GPRS subsystem.

With this test methodology, the protocol implementation can be verified in all relevant aspects. For example, does the protocol implementation conform to the standard? Is it robust enough to sustain abnormal behaviour / unexpected error conditions? Do memory leaks occur during long duration stability tests?

Such a test scenario can also be combined with Error Insertion, which is a deterministic approach for simulating abnormal situations. With this feature the test engineer can inject irregular procedures into the flow for a certain number of subscribers. There are large numbers of predefined error conditions the test engineer can choose from. For example, it is possible to reproduce loss of radio connectivity, to simulate non-conforming handsets (that duplicate messages, for example) or to simulate mal-configured terminals (that try to connect to a non-existing APN, for example). Every error will be injected in a pseudo-random way for a certain percentage of subscribers. Different error conditions can be mixed with each other.

The effects of abnormal and error conditions often remain unknown because they can not be tested within real network nodes. An example of such an abnormal condition is a collision of a user initiated PDP Context Activation and a network-initiated DETACH procedure. The expected network behaviour in the event of abnormal situations is usually not fully specified in the standards.

The combination of load and functional testing is a new test paradigm. It eliminates the inherent disadvantages of isolated load / functional testing.

The G35 is designed to support the simulation of real-world load and stress test scenarios. One key element lies in the ability to generate both control and user plane traffic. Every PDP context can individually be linked to a certain user plane load profile. With the G35, it is possible to activate up to eleven PDP contexts per MS, whereas every PDP context is related to another load profile.

The user plane content can be generated internally by the simulator. It is also possible to inject external content (for example: web browsing, video streaming from an external video server) into the user plane tunnel.

In a complex ecosystem, symptoms and root cause are often far apart from each other. A single mis-calculated or corrupted quintuplet distributed from the HLR to the SGSN (Gr-Interface) can cause an error in the integrity check between SGSN and RNC (IuPS-Interface). For thorough troubleshooting, the G35 combines monitoring and active test capabilities.

Let's assume an operator wants to simulate an access network with 100,000 mobile subscribers and also wants to monitor the traffic in the core network (to network nodes such as HLR, CAMEL Center, etc.). We further assume that the complete network is IP-based. Under these conditions, the investment in test and measurement tools will be considerably lower than in the past because the operator needs to only invest in a G35 with one Ethernet board. The Ethernet board can be used for concurrent active (load generation) and passive testing (monitoring). Separate protocol monitoring equipment is not required.

The G35 offers a large number of statistics and counters to support analysis tasks. The test results can be imported into an Excel file or into a database to support the generation of detailed reports.

Push Services

Typical telecommunication and Internet services like web browsing are considered to be pull services. The end-user initiates the transaction and requests content such as a certain web page. Push services, on the other hand, refer to a communication method whereby the transaction is initiated by a central instance (for example: PoC Server or Broadcast / Multicast Server). Push transactions are often based on a subscription model. The user needs to inform the central instance in advance that certain information (sport news, weather forecast) shall be delivered whenever new content is available.

Two push services have been introduced with 3GPP Release 6. In this section, we take a closer look at them and how these services affect the GPRS subsystem.

Push-to-talk-over-Cellular

Push-to-talk-over-Cellular (PoC) is a new standard that offers effective and simple voice communication between user groups. A precondition of this standard is that the user has subscribed to one or more user groups. The user equipment offers the possibility to manage PoC service settings and to compile group lists. The corresponding protocols are called XCAP (XML Configuration Access Protocol) and XDM (XML Document Management).

After SIP signaling is exchanged among all group members, the voice stream (known as a Talk Burst) will be transmitted from the initiator to the PoC server. The server will then distribute the Talk Burst to all participants in the user's group. Only one user at a time can own the "floor" and send voice data to the PoC server; this is what makes this service "walkie-talkie" like. The Talk Burst Control Protocol (TBCP) is responsible for controlling the allocation of 'floor' to PoC participants. This includes sending a notification that a user has been granted the floor and will now be heard by the other participants.

Resource efficiency is an advantage of the PoC service. The user's speech information is segmented and transmitted over the packet-based GPRS Subsystem. Unlike typical duplex communication services, only a unidirectional user plane channel is required. The packet-oriented technology may cause quality degradations such as introducing a delay of~2 seconds to the speech frames. However, the achievable voice quality usually is sufficient for this type of application.

Mobile Broadcast / Multicast Service

Mobile Broadcast / Multicast Service (MBMS) is an IP datacast service, that is, a suitable method for transferring content such as video and audio clips to a large number of recipients. Thus, the MBMS is a unidirectional point to multipoint bearer service in which data is transmitted from a single source to multiple recipients. 3GPP has defined two modes of operation [8]:

- Broadcast Mode
- Multicast Mode

The broadcast mode is an efficient method of sending information to all users in a broadcast service area (for example, thunderstorm warning). The multicast mode is based on a subscription model (a service providing sports scores for which a subscription is required).

There are some high level requirements that apply to Multimedia Broadcast / Multicast Services [8][9]:

- An MBMS notification procedure shall be used to indicate the start of the MBMS data transmission
- A mechanism shall be defined to enable the network to start the MBMS data transmission for a multicast session in a cell if there is at least one user in this cell
- A mechanism shall be defined to stop the MBMS data transmission for a given multicast session in a cell which no longer contains any active user

The RANAP procedures between RNC and SGSN for MBMS Service Activation and Session Start are shown in figure 9.

The SGSN initiates the MBMS MS linking procedure by sending a RANAP *MBMS UE Linking Request*. It does this in order to provide the RNC with the list of MBMS services activated by this MS. On the right hand side, a screenshot displays the structure of this message, which was created with the G35 Message Building System (MBS). The message is composed of four sequences, and each sequence contains the PLMN Identity (*pLMNidentity*) and the Service Identifier (*serviceID*). In this example, the RNC was informed that this particular user had activated four different services. *pLMNidentity* and *serviceID* are represented by variables, because these parameters are also required in other messages of the depicted flow (for example, *MBMS Session Start*).

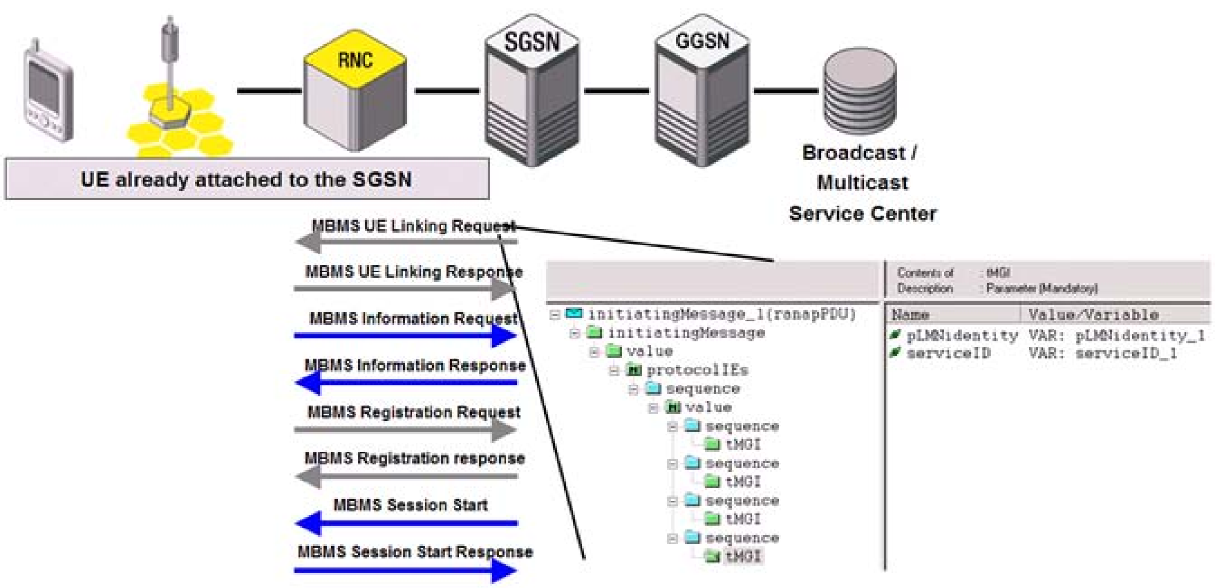

Figure 9. MBMS Service Activation and Session Start

The RNC then confirms with *MBMS UE Linking Response*. As the RNC has no MBMS context for this service (because it was the first MS to have this service activated), it does not know the IP Multicast address or APN for this service. The RNC requests this information from the SGSN using the *MBMS Information Request* message. SGSN responds with a *MBMS Information Response* message (Parameters: IP Multicast address, APN). After the service context is created, the RNC sends a *MBMS Registration Request* message and notifies the Core Network that it is ready to receive the *MBMS Session Start* message. After *MBMS Registration Response*, *MBMS Session Start* and *MBMS Session Response*, the downlink data transfer is established.

How will the GPRS subsystem be affected by these services? Obviously, it can be expected that these services will cause a significant increase of user plane traffic. The traffic model becomes more unpredictable because there is an increasing level of uncertainty regarding the cells that need to be served. Various datacast services will compete against each other for bandwidth. Therefore, the implications for QoS are:

- The reception of traffic in the broadcast area is not guaranteed; The receiver may experience data loss
- MBMS does not support individual retransmissions
- For the sake of traffic reduction, there must be the possibility for the network operator to transmit multicast information to only those cells in the designated multicast area which contain members of the multicast group
- The network operator must be able to configure the QoS individually for each and every broadcast service
- It should be possible to adapt the MBMS data transmission to different RAN capabilities or to the current available radio resources
- In the event of network resource limitations, the operator should be able to define rules in which broadcast services will or will not be supported

Outlook

The standardization of GPRS was initiated by ETSI's SMG (Special Mobile Group) in 1994. The main set of GPRS specifications was approved by SMG #25 in 1997 and completed in 1999. The original conceptual design of GPRS was a packet-switched subsystem – a vertical extension to the circuit-switched GSM core network.

GPRS will outpace the circuit switched subsystem completely in the next few years. This trend is reinforced by the efforts of many network equipment vendors to develop and standardize new access technologies for the GPRS packet switched domain, such as UMA and Femto Cells.

The mobile network architecture of the future will be horizontal as highlighted in Figure 10 – the architecture of a 4G IP-based integrated network. SGSN and GGSN form the core elements of the transport network. With the arrival of LTE, both elements will evolve into two new elements denoted as MME (Mobility Management Entity) and SAE-Gateway (System Architecture Evolution).

Both SGSN and GGSN play a vital role in ensuring smooth operation now and seamless integration of future services into the mobile ecosystem.

The purpose of every communication system is not the technology itself, but the reliable support of applications and related QoE as perceived by the end user.

For network operators and equipment manufacturers, it is crucial to understand how a heavily loaded GPRS subsystem behaves and how the GPRS network is impacted by the introduction of new services with various performance requirements.

Many new services, like PoC and MBMS, won't be deployed before early 2009. Although the first terminals will appear in 2008, it will take several years until these services become mass market services.

Understanding the performance characteristics of these and other services as they are delivered under full load is the cornerstone of an effective GPRS test methodology. As the Yankee Group states, "Test vendors must be able to emulate both the complexity and scale of the network before any service can be rolled out with confidence" [11].

The Tektronix G35 accomodates all required test capabilities on one single platform. Unique features like simulation of all surrounding networks elements, error insertion, high performance and a large number of mobile protocols are the foundation for comprehensive Functional, Load and Stress Testing, not only exclusively but also for GPRS. The G35 and its predecessor K1297-G20 are used by all major network operators and network equipment manufacturers worldwide. This expertise renders the G35 a proven and reliable test and measurement tool.

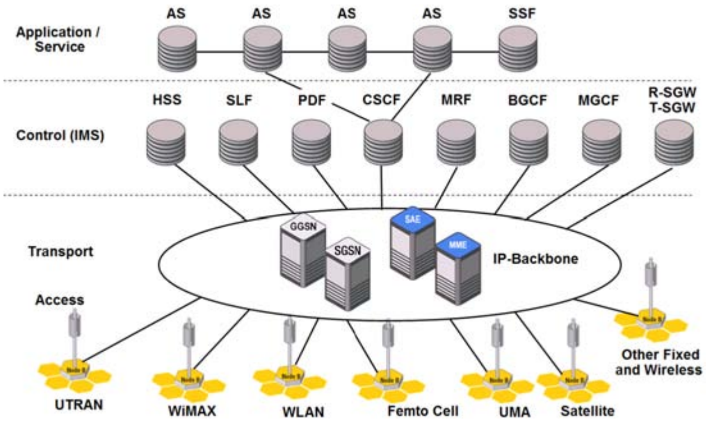

Figure 10. 4G IP-based integrated net¬work

Abbreviations

AA (Request, Response)	Authentication & Authorization	Diameter messages
APN	Access Point Name	Name of an external IP Router
AS	Application Server	IMS node that delivers applications to mobile (phone, PDA) or other devices (laptop), typically using SIP and Hypertext Transfer (HTTP) Protocol
ATM	Asynchronous Transfer Mode	53-Byte cell relay mechanism
BGCF	Breakout Gateway Control Function	SIP server that includes routing functionality based on telephone numbers. It is only used when calling from the IMS network to a phone in a circuit switched network, such as the Public Switched Telephone Network (PSTN) or the Public Land Mobile Network (PLMN).
BM-SC	Broadcast-Multicast Service Center	Network node for delivering broadcast-multicast services
CAMEL	Customized Applications for Mobile Enhanced Logic	Protocol for intelligent services (for example, prepaid calls) in mobile networks
CN	Core Network	Central part of a telecom network that provides various services (authentication, authorization, billing, etc) to subscribers that are connected by the access network.
COPS	Common Open Policy Service	Internet Engineering Task Force (IETF) protocol used for general administration, configuration and enforcement of policies
CSCF	Call Session Control Function	Network Node of the IMS subsystem
DNS	Domain Name Service	Service that translates hostnames to IP addresses
EIR	Equipment Information Register	Central database that stores the hardware address (International Mobile Equipment Identifier) for each mobile phone
ETSI	European Telecommunication Standard Institute	European standard institute located in Sophia-Antipolis, France
GERAN	GPRS / EDGE Radio Access Network	GSM / GPRS access technology that offers connectivity between MSs and the 2G / 2.5G core network
GGSN	Gateway GPRS Support Node	Network node that acts as a gateway between the GPRS network and other packet data networks such as IMS or Internet
GPRS	General Packet Radio Service	Packet switched extension of GSM networks; also often described as “2.5G”
GSM	Global System for Mobile Communication	2nd-generation mobile network (2G)
HLR	Home Location Register	Central database that stores permanent (for example, telephone number, subscribed services) and temporary (for example, current location) information of each mobile subscriber
HSDPA	High-Speed Downlink Packet Access	Enhancement of the UMTS Radio Access Network for up to 14.4 MBit/s gross bit rate. Commercial available systems (2007) offer 2 Mbit/s net bit rate.
HSS	Home Subscriber Server	One of the nodes of the IP Multimedia Subsystem; a central database for subscriber, security and service information. Function like HLR with additional IMS functionality using DIAMETER messages
HSUPA	High-Speed Uplink Packet Access	Pendant to HSDPA for broadband uplink connectivity.
IE	Information Element	Part of a protocol message
IMS	IP Multimedia Platform	Network subsystem; Architectural framework for delivering internet protocol (IP) multimedia to mobile users
IP	Internet Protocol	Internet Protocol, defined in RFC-791 (1981)
MBMS	Mobile Multicast / Broadcast Service	3GPP R6 Unidirectional Point-to-Multipoint Multimedia Service
MBS	Message Building System	Element of the simulation tool chain of the protocol test device G35
MCC	Mobile Country Code	Mobile network country code MCC and MNC are unique identifiers for every mobile network.

MGCF	Media Gateway Control Function	IMS function offering connectivity between traditional circuit-switched mobile users and IMS users. Performs mapping from IMS SIP signalling into circuit switched signalling (BICC, ISUP) and vice versa.
MME	Mobility Management Entity	4G mobile core network node
MNC	Mobile Network Code	Mobile network code MCC and MNC are unique identifiers for every mobile network.
MRF	Multimedia Resource Function	Provides media-related functions such as media manipulation (for example, voice stream mixing) and playing of tones and announcements
MS	Mobile Station	Mobile device (mobile phone, PDA, etc.) ; same as UE
PCO	Protocol Configuration Options	Information Element, for embedding higher layer messages (IPCP, for example) into a GPRS message
P-CSCF	Proxy-Call Session Control Function	First point-of-contact within the IMS subsystem.
PDF	Policy Decision Function	Function in an IMS network; Notes and authorizes IP flows of the chosen media components
PDN	Packet Data Network	External packet switched network connected to a GPRS network
PDP	Packet Data Protocol	Network protocol used by an external packet data network interfacing to GPRS.
PoC	Push-to-Talk over Cellular	3GPP R6 Unidirectional Point-to-Multipoint Voice Service
QoS	Quality of Service	Resource reservation control mechanism in a telecommunication network
R-SGW	Roaming Signalling Gateway Function	IMS Gateway offering connectivity to legacy mobile networks
RAC	Routing Area Code	Cluster of network cells
RANAP	Radio Access Network Application Part	UMTS signalling between the Access (RNC) and Core Network (SGSN)
RNC	Radio Network Controller	Node or the UTRAN subsystem; responsible for radio resource management and mobility management
SAE-Gateway	System Architecture Evolution Gateway	4G mobile core network node
SGSN	Serving GPRS Support Node	Node in the GPRS subsystem, responsible for IP packet transfer, mobility management, logical link management, authentication and charging
SIP	Session Initiation Protocol	Control Protocol, widely used for Voice over IP and IMS
SLF	Subscription Locator Function	Function in the IMS subsystem for HSS recovery
SMG	Special Mobile Group	Export Group from ETSI
SMS	Short Message Service	GSM standards from 1985; sending text messages of up to 160 characters
SSF	Service Switching Function	Logical function in the IMS network offering connectivity to CAMEL application servers using the CAMEL application part protocol (CAP)
T-SGW	Transport Signalling Gateway Function	IMS Gateway offering connectivity to legacy fixed networks (PSTN)
TBCP	Talk Burst Control Protocol	Protocol defined by the Open Mobile Alliance, used for PoC services
TFT	Traffic Flow Template	Filter for downlink user data transfer, which will be distributed from MS to the GGSNs during PDP Context Activation procedure
tMGI	Temporary Mobile Group Identity	Information element of MBMS RANAP messages
UE	User Equipment	Mobile device (mobile phone, PDA, etc.)
UMA	Unlicensed Mobile Access	Access technology allowing seamless roaming and handover between Wireless LAN and GSM/UMTS networks using a dual-mode mobile phone.
UMTS	Universal Mobile Telecommunication System	3rd-generation mobile network

UTRAN	UMTS Terrestrial Radio Access Network	UMTS access network that offers connectivity between MSs and the UMTS core network
WiMAX	Worldwide Interoperability for Microwave Access	Telecommunication technology based on the IEEE 802.16 standard
WLAN	Wireless Local Area Network	Wireless indoor telecommunication technology based on the IEEE 802.11 standard
XCAP	XML Configuration Access Protocol	Language used for adding, deleting and manipulating data on IMS application server Required for IMS services like Presence, Conferencing, Messaging, etc.
XDM	XML Document Management	Service specified by the Open Mobile Alliance. Specifies documents that can be shared by multiple services Required for Group List Management
XML	Extensible Markup Language	General-purpose language. Its primary purpose is to facilitate the sharing of structured data across different information systems, particularly via the Internet

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10/08 | CPW-22995-0

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