AN INTRODUCTION TO THE VODAFONE GPRS ENVIRONMENT AND SUPPORTED SERVICES

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Amendment Record

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Draft A1	01/08/2000	Changes identified by NP and AC incorporated by ND.
Draft A2	01/08/2000	Changes to section on ‘Bandwidth’
Draft A3	14/08/2000	Added two new appendices; ‘Throughput Calculations’ and ‘GPRS Network Architecture.’
		Corrected +CGREG to +CGREQ in Mitsubishi example.
Issue 1.0	23/08/2000	Added appendix describing GPRS Connection Script. Raised to issue level, ND.
Issue 1.1	17/12/2000	Updated for new handsets and software, NP
		Additions made for Motorola T260 and Ericsson R520 handsets
		Modified to include Wireless Login Client software
		Additional information about development area LAN configuration and facilities

References

[No.]	Document Name	Issue
1	GSM 02.60: “Digital Cellular Communications System (Phase 2+); General Packet Radio Service (GPRS); Service Description, Stage 1”	V8.1.0 1999
2	GSM 03.60: “Digital Cellular Communications System (Phase 2+); General Packet Radio Service (GPRS); Service Description, Stage 2”	V6.7.0 1997
3	GSM 07.60: “Digital Cellular Communications System (Phase 2+); General Packet Radio Service (GPRS); Mobile Station Supporting GPRS”	V6.5.0 1997
4	GSM 07.07: “Digital Cellular Communications System (Phase 2+); AT command set for GSM Mobile Equipment (ME)”	V7.3.0 1998

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Abbreviations

APN	Access Point Name
bps	Bits per second (Not bytes). Often measured as multiples of 1024, i.e. Kbps.
BSC	Base Station Controller
BSS	Base Station System (BTS+BSC+PCU)
BTS	Base Transceiver System
CGSN	Combined GPRS Support Node (SGSN+GGSN)
GGSN	Gateway GPRS Support Node
GPRS	General Packet Radio Service
GSM	Global System for Mobility
GTP	Gateway Tunnelling Protocol
HLR	Home Location Register
IP	Internet Protocol
Kbps	See bps.
L2P	Layer 2 Protocol
LLC	Logical Link Control
MAC	Medium Access Control
ME	Mobile Equipment
MO	Mobile Originate
MS	Mobile Station
MT	Mobile Terminate
PAD	Packet Assembler/Disassembler
PCU	Packet Control Unit
PDN	Packet Data Network
PDP	Packet Data Protocol, e.g. IP, X.25
PLMN	Public Land Mobile Network, i.e. a mobile telephone operator.
PSTN	Public Switched Telephone Network, i.e. a fixed line telephone operator.
QoS	Quality of Service
RLC	Radio Link Control
SNDCP	Subnetwork Dependent Convergence Protocol
SMS	Short Message Service
SMSC	Short Message Service Centre
TA	Terminal Adapter
TCP	Transmission Control Protocol
TE	Terminal Equipment
UDP	User Datagram Protocol
V.250	ITU-T Specification, formally known as V.25ter

1. INTRODUCTION

GPRS is a communications bearer service. This means nothing more than that it is a different underlying method for managing the end-to-end transfer of data, where one or both ends are GPRS compatible Mobile Stations (MS). There are, however, some limitations regarding Mobile Terminated (MT) data that are discussed later.

GPRS is particularly suited to bursty traffic, as experienced when browsing the Internet and synchronising E-mail with a remote server. It is not suited for voice calls, where there is continuous traffic. The pros and cons of packet switched methods vs. circuit switched methods are not discussed here.

Browsing the Internet typically consists of periods of data transfer interspersed with long periods of inactivity. The packet nature of GPRS is what allows the service to utilise the air bandwidth in a more efficient manner than GSM and to allow the bandwidth to be shared with other users.

GPRS connectivity is provided by a ‘context’, which is specified at the Packet Data Protocol (PDP) layer. The Internet is a Packet Data Network (PDN) with IP as its PDP and is the first type of PDN to be supported by GPRS.

The Terminal Equipment (TE, i.e. software on a computer) must be able to manipulate the various transport layer protocols, such as TCP and UDP. This guide describes both the AT commands used to control a typical GPRS device when in command mode and the use of utilities that already know how to deal with TCP/UDP packets, such as Dial-Up Networking in Microsoft Windows.

This document is intended to provide an overview of the new functionality that has been defined by ETSI for use with GPRS compatible Mobile Equipment. It focuses on the interface between the Terminal Equipment and the network, providing examples appropriate to the Vodafone GPRS test network.

Three particular GPRS handsets are dealt with here, the Ericsson R520 prototype, the Motorola T260 and the Mitsubishi Trium, with the emphasis being on the first two. In discussing the setting up of a GPRS connection, some background knowledge of serial communications, AT commands and Windows communications is assumed.

1.1 ETSI GSM Technical Specifications

Detailed descriptions of the service can be found in ETSI GSM 02.60[1] and GSM 03.60[2].

The MS operation, such as PDP context activation and interfacing to external PDNs as described in GSM 07.60[3] is covered here.

The AT commands defined for the service are introduced, although this reference is not intended to provide a detailed guide of the syntax and responses for every command. The full list of cellular AT commands and their syntaxes can be found in ETSI GSM 07.07[4].

Extracts from some of the ETSI documents listed in the References section are used here with permission. Original documents are available from

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1.2 GPRS MS Functionality

ETSI have defined three classes for GPRS MS functionality. Class-A supports simultaneous GPRS and GSM traffic, Class-B supports switching circuits between the two while Class-C supports operation in only one mode at a time.

Table 1 - GPRS MS Class Descriptions

Handset Class	Functionality
A	GPRS and GSM simultaneously
B	Either of GPRS or GSM at any given time
C	GPRS or GSM exclusively
CG	Class-C in GPRS only mode
CC	Class-C in circuit switched only mode (lowest mode)

Class-A handsets will be able to support simultaneous attach, activation, monitoring, invocation and data transfer in both GPRS and GSM modes. Calls can be made or received on both services subject to the QoS parameters.

Class-B will be able to attach to, activate and monitor both services simultaneously but only be able to support data transfer on one at a time. Active GPRS virtual circuits are not cleared down when GSM facilities are in use, but any attempt to contact the PDP address will result in a “busy or held” indication. For instance, if an incoming GSM call is answered, the GPRS connection is put on hold. This may cause problems for some applications using the GPRS connection, e.g. a file transfer may be aborted because the transfer protocol timeout expired.

It is anticipated that some Class-B devices will be available in time for the launch of the service. Class-A handsets will be available at a later date.

Class-C handsets will only be able to operate exclusively in one mode at a time, i.e. non-simultaneous attaches. Manually changing from one mode to the other involves detachment from the previously selected service.

The AT command ***AT+CGCLASS*** will indicate the current mode and which modes are supported.

The range of PDPs and L2Ps supported by a given handset is independent of the class of the device, although it is envisaged that the more sophisticated the class, the more PDPs may be supported, e.g. X.25 in addition to IP. Availability of services at the handset is also dependent upon the services offered by the network and Vodafone have no plans, at present, to support services other than IP.

1.3 Modes of Connectivity

A conventional GSM device is either switched on or it is switched off. When it is on, it is attached to the network and the HLR tracks the device to know which Base Station it is registered on.

When in a call, a conventional GSM device maintains a dedicated circuit from endpoint to endpoint. The MS is the sole user of one single timeslot across the air interface and a **circuit switched** connection is set up through the network, which again, is not shared with any other party. Even when no data is being transmitted, the resources are still consumed whilst in the call.

GPRS is an extension of GSM. Therefore the MS is registered with the network in a similar way and the network tracks the location of it so that it knows where data packets should be sent. An **Attach** is made with the **SGSN** rather than the HLR and the serving GPRS cell is tracked.

For devices capable of supporting simultaneous GSM and GPRS attach (Class-A and Class-B), the device may be registered on different cells for GSM and GPRS as it sees fit.

An attached GPRS device may activate one or more **contexts**. When a context is active, the device is assigned a **PDP Address** (which may have been specified by the device, i.e. static IP addressing), so that devices on the same or other connected networks may reach it. The host of the PDN provisions dynamic IP addresses, so that the GPRS MS looks like any other device physically located on that network.

The GPRS test network only supports static IP addressing at present. Each developer will be informed of the IP address associated with the handset that they are using. Dynamic addressing will be introduced early on during the trials.

When an attached GPRS device sends or receives data it makes use of shared network resources. Unlike conventional GSM, it is not the sole user of the radio channel or of any other network resource. A **virtual circuit** is established for each communication. This means that although the channel has the appearance of an end-to-end data pipe, individual data packets may take very different routes through the network.

1.4 The PDP Context

The Mobile Station establishes a context when it decides it requires a presence on a Packet Data Network. If a MS does not have an active context, it cannot be contacted at all via the GPRS network.

When attached, a GPRS device can send and receive data packets just like any other IP device. In fact, the GPRS standard allows the MS to specify the PDP (Packet Data Protocol) and even the layer two protocol (L2P) to use. GSM 07.07 lists the following PDP and L2P values;

Table 2 - Full List of GPRS PDP Types

PDP Type	
IP	Internet Protocol (IETF STD 5)
OSPIH	Internet Hosted Octet Stream Protocol
X25	ITU-T/CCITT X.25 layer 3
PPP	Point to Point Protocol (IETF STD 51)

Table 3 - Full List of Layer 2 Protocols

Layer 2 Protocols	
NULL	None, for PDP type OSP:IHOSS
PPP	Point-to-point protocol for a PDP such as IP
PAD	Character stream for X.25 character (triple X PAD) mode
X25	X.25 L2 (LAPB) for X.25 packet mode
M-xxxx	Manufacturer-specific protocol (xxxx is an alphanumeric string)

Please consult manufacturer specific documentation to determine the range of protocols supported by an individual device.

1.5 Mobile Terminated GPRS Data

Data can only be received at a GPRS device if the device is attached to the service and has an active context in an accessible address space. Under such conditions, IP packets can be sent to the mobile as if it were any other device on the IP network. It is then up to the application to decide what to do with the incoming data.

A context can only be activated by the mobile station. If the GPRS device does not have an active context, and therefore no PDP address, alternative methods of communicating with it must be considered.

It is generally recommended (a recommendation that extends to circuit switched GSM too) that Mobile Originated (MO) calls are preferred to Mobile Terminated (MT) ones. Statistics show that call success rates are far higher for MO than MT and some of the reasons include the fact that the Mobile Station may be busy, switched off or out of coverage at the time when the calling party is trying to reach it.

Many mobile applications involve a fixed or static host that is typically available. Therefore the mobile is more likely to reach the host at any given time, provided enough circuits are available, than vice-versa.

Network initiated context activation will not be possible within GPRS for some time. The device has no PDP address and so the GPRS network cannot reach it. There are currently no other GPRS specific methods by which the device can be contacted.

For Class-A and Class-B GPRS devices it may be possible to make a mobile terminate GSM transmission (a data call or an SMS) to request that the device activate a context and issue a reply to the remote party. This is a perfectly acceptable scenario, subject to the conditions of those classes.

A Class-C device that only supports GPRS, or that is not currently operating in GSM mode will not be able to accept a MT GSM call and so cannot be requested to attach in this way. If a Class-C device can support both GSM and GPRS modes then it is advised that the device remain in GSM mode when not active on the GPRS service.

1.6 GPRS Bandwidth and Throughput

The bandwidth available to the GPRS user is dependant upon several factors. In order to increase the bandwidth per channel, a different **Coding Scheme** can be chosen, but this is at the expense of reduced error protection

ETSI have defined four coding schemes, from CS1 (highest error correction, lowest data rate) to CS4 (no error correction, highest data rate). The Vodafone GPRS network, and most handsets, will only support CS1 and CS2. The high incidence of errors when CS3 and CS4 are used prohibits their use under most circumstances.

The second way of increasing bandwidth is to utilise multiple timeslots. Handsets will be described by the maximum number of timeslots that they can use on the downlink, plus the number of timeslots that they can use on the uplink, for instance '2+1', '4+1', '3+2'. It is expected that the majority of data will be received by the handset rather than transmitted by it.

Timeslots will be dynamically allocated according to availability. Up to 8 timeslots are available on any given channel within a cell and the management of resources will be negotiated between the handset and the network. GSM will generally take priority over GPRS and so from time to time availability may be reduced as the number of voice callers rises. However, the advantage of GPRS is that as soon as a timeslot becomes available it can benefit many data users.

Table 4 lists the theoretical maximum transmission rates (throughput) using the different coding schemes and utilising one or more timeslots. Up to four timeslots may be available for GPRS on a given live cell, but this may be dynamically adjusted against the requirements of GSM users on the same cell when the service becomes live. Under coding scheme 2 (CS2) for example, each timeslot provides 13.4Kbps (K bits per second). This provides a payload of approximately 12Kbps.

Table 4 - Throughput Capabilities of GPRS

	Coding Scheme 1 (CS1)	Coding Scheme 2 (CS2)	Coding Scheme 3 (CS3)	Coding Scheme 4 (CS4)
1 Timeslot	9.05 Kbps	13.4 Kbps	15.6 Kbps	21.4 Kbps
2 Timeslots	18.1 Kbps	26.8 Kbps	31.2 Kbps	42.8 Kbps
3 Timeslots	27.15Kbps	40.2 Kbps	46.8 Kbps	64.2 Kbps
4 Timeslots	36.2 Kbps	53.6 Kbps	62.4 Kbps	85.6 Kbps

A detailed example describing how to calculate the realistic throughput can be found in Section 8.

1.7 What About WAP?

Wireless Application Protocol, WAP, allows mobile equipment to browse the Internet. It is a bearer independent service and therefore will run over GPRS as well as GSM.

GPRS handsets supporting WAP V1.1 will be available from about October 2000 and handsets supporting WAP V1.2 will be available at the launch of the service.

In the interim, WAP emulation software can be run on the PC to convert data and present it, as would a dedicated WAP phone. Such an application may be included in the development environment provided.

2. GETTING STARTED

The development suite consists of an office area with seating space for two developers and a Vodafone support engineer. A workstation PCs is supplied, networked into the GGSN of the GPRS network. This can be booted into either Windows NT 4, or Windows 2000 and is intended for use on the server-side of applications testing. A standalone laptop bootable into Windows 98 or Windows 2000, and with various GPRS utilities, is available for use with the GPRS handsets. A range of GPRS handsets is available to developers. The models currently available are:

- Ericsson R520
- Motorola T260
- Mitsubishi Trium

Alternatively, GPRS SIMs suitable for use on the test network can be supplied to developers who prefer to use their own handsets.

We will try to accommodate requests for additional equipment or different operating systems but it will not always be possible or practical for us to do so. In general, the final responsibility for machine configuration lies with the developer.

The most accessible method of demonstrating and using GPRS is via the Dial-up Networking facilities of Microsoft Windows, or similar facilities provided by other operating systems. For the purposes of these examples, Dial-up Networking will be referenced. In practice, any TCP/IP protocol stack should be able to be used.

The software on the laptop includes;

- Reflection – A terminal application
- Assorted TCP/IP demonstration utilities suitable for GPRS
- The Vodafone Wireless Login Client software

The network configuration of the development suite is illustrated below. The PC is connected to the GPRS test network node. By putting the phone in the same office, an end-to-end testing environment is obtained, where developers can control both client and server sides of their application.

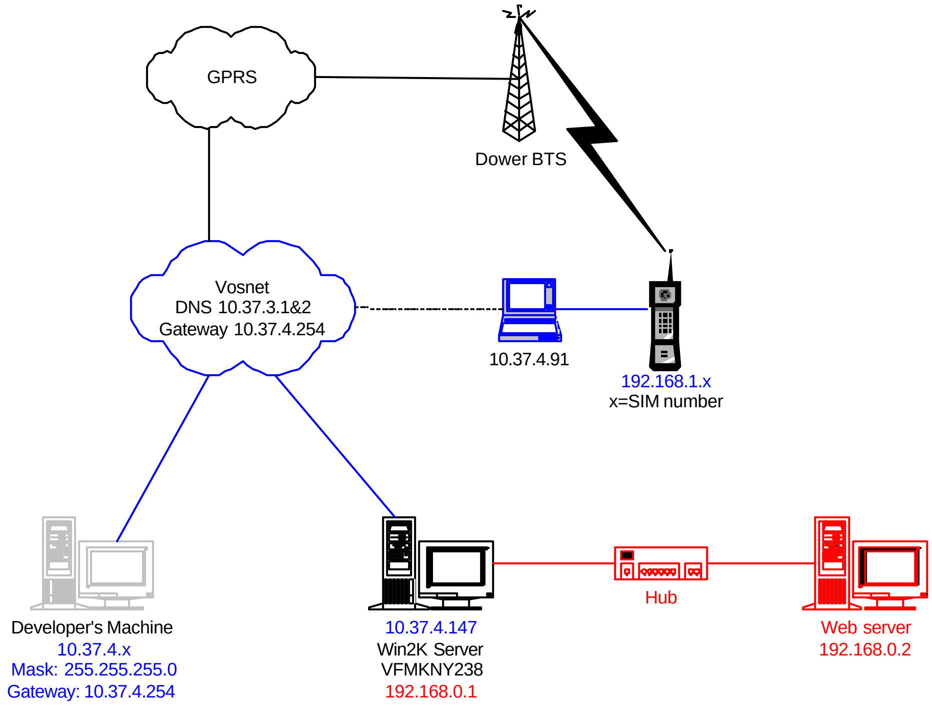

Figure 1 - The Vodafone GPRS Development Environment

2.1 Caveats

In the early stage of the GPRS programme, the network control nodes are running prototype software versions. The test network may therefore suffer occasional outages, sometimes without notice.

Similarly, the GPRS handsets in use are generally still prototypes. Their software is frequently being upgraded and consequently the information given in this document may not be up-to-date. The phones themselves will not be as stable, well behaved or well documented as would be expected of production handsets.

Vodafone-owned development machines will generally be restored to a clean state between uses by different business partners, however ***Vodafone cannot be held responsible for the security of software or data left on its computers after testing***. The onus is on developers to remove sensitive information from Vodafone equipment.

2.2 Preliminary setup

The TA and laptop normally use a serial interface to communicate. Both the Motorola and Ericsson phones support cable and IR serial connections. Actual connectivity details will depend on the type of connection, the operating system on the laptop and the software being used.

1. Power on the laptop and allow to boot
2. Power on the phone
3. Check that the phone has attached[1] to the test network. Depending on the phone, this will generally just involve looking for the text *`PTT Telecom`* appearing in the display.
4. For phones with direct cable connection, make all necessary connections. For infrared connectivity, line up the IrDA ports on the phone and the laptop so that a link can be established. The valid I/R link will be confirmed in the System Tray.

2.3 Connecting with Reflection and Dial-up networking

This section describes how to use standard Windows facilities to perform the context definition, attach and context-activation steps. These instructions should be easily adaptable to different platforms (e.g. PDAs) and operating systems. Some form of communications package is required to issue the commands to the handset, and we have used Reflection as it supports scripted commands (including waiting for responses). The commands could also be issued directly from HyperTerminal, which comes as a standard component in all desktop Windows versions.

2.3.1 GPRS Attach and Context Activation

Before Dial-up Networking can be used, AT commands must be issued to the phone to attach to the GPRS service and activate a valid context. Some handsets automatically attach The AT commands required for this are stored in a macro.

1. Open the Reflection session for the GPRS device being used. A shortcut to a session that has already been configured for the specific device will be present on the desktop.
2. Type *`AT`* and verify that *`OK`* is received. If so, proceed. Otherwise, check the setup and configuration, then resume.
3. There are three customised buttons in the toolbar, labelled ‘Attach’, ‘Set IP Address’ and ‘Detach’.
4. Click ‘Attach’[2] and wait for the ‘OK’ response. You should see:

```
AT+CGATT=1
OK
```

5. Click ‘Set IP Address’ and wait for the three AT commands to be issued and receive a positive response. Depending upon the GPRS phone provided, you may see:

---

[1] Depending on the handset, this may be a GPRS Attach, or it may just be an IMSI (traditional GSM) Attach to the test network.

[2] If the phone has automatically GPRS-attached on power-up, this is of course redundant. It doesn’t do any harm in any case though.

```
Ericsson Session:
AT+CGDCONT=1,"IP","WWW.ERICSSON.SE","192.168.1.9",1,1
OK
AT+CGQREQ=1,2,1,3,9,18
OK
AT+CGQMIN=1,2,1,3,9,18
OK

Motorola Session:
AT+CGDCONT=1,"IP","WWW.ERICSSON.SE","192.168.1.9",1,1
OK
AT+CGQREQ=1,2,1,3,9,18
OK
AT+CGQMIN=1,2,1,3,9,18
OK

Mitsubishi Session:
AT+CGDCONT=1,"IP"," WWW.ERICSSON.SE","C0A80109"
OK
AT+CGQREQ=1,2,1,3,9,18
OK
AT+CGQMIN=1,2,1,3,9,18
OK
```

Note that there are some differences between the syntaxes of the commands listed above. Some parameters are optional within the string, which is why there are a varying number of parameters in the *AT+CGDCONT* command.

However all the context definition commands have specified a static PDP address to be used as the IP address of the GPRS connection. The Ericsson and Motorola devices require this to be specified in **decimal** format, e.g. *"192.168.1.9"*, but the Mitsubishi requires the IP address to be specified as a **hexadecimal** value, e.g. *"C0A80109"*. The parameter itself is a string value, although the quotation marks may be omitted. On the test network, static addresses are simply 192.168.1.x where x is the number o

If *ERROR* is returned to any of the commands, issue *AT* so as to solicit an OK response. This will allow the macro to complete, after which you should try and determine why the command could not execute successfully (Is the phone properly connected and switched on?).

6. 'Disconnect' the reflection session (Icon should become) and minimise the window. At this point, the TA is attached to the GPRS network. It does not yet have an *active* context; the context has merely been *defined*. Disconnecting the Reflection session allows Dial-Up Networking to be able to use the device by freeing up the COM port. Minimising the Reflection session will also remind you to perform a full detach when finished.

2.3.2 Dial-Up Networking

A GPRS device that is attached on the network and has a context defined locally may activate that context on the network and commence data transfer or remain idle.

It is possible to activate a context manually by issuing the appropriate AT commands, but context activation will be carried out implicitly when the GPRS service is dialled.

The AT Dial command is supported within the GPRS subset of commands for backwards compatibility. The **Service Code** that is dialled is always 99, but other parameters may be specified hence the actual dial string used for the Ericsson and Trium is **99***1#*, while for the Motorola it is **99#*. The format of this string is explained further on. The Dial-Up Networking sessions have already been configured with this number.

A shortcut to the default Dial-Up Networking sessions for both the Ericsson and Mitsubishi devices are located on the desktop. Double click these and click 'OK' in the dialog box. No password is required.

When the session is established, an icon will be placed in the system Tray indicating the connection status. For more detailed statistics, the tool Dial-Up Networking Monitor may be used.

2.3.3 Ending The Session

It is important to detach properly from the GPRS network.

1. Disconnect the Dial-Up networking connection
2. Restore the Reflection window
3. Reconnect to the device by clicking the connect/disconnect button in the toolbar (Icon should become )
4. Click 'Detach' from the toolbar

The Reflection window may be closed if desired.

2.4 Connecting with Vodafone's Wireless Login Client

The Wireless Login Client automates the setting up of a GPRS connection, including setting the IP address, defining the context, performing an Attach and setting up the context. Documentation and help for this software, and the program itself, can be obtained when using the development facility.

2.5 Testing the IP Link

To test the GPRS link, open a DOS window and enter

```
ping 192.168.186.97 –w 5000
```

This will ping the ISP server attached to the GPRS Gi interface. The `–w 5000` is to ensure enough time is left for a response to be received.

You should then be able to obtain an IP connection through to the server side of the application under test. If access to Web content is required this can usually be arranged via a proxy server.

3. IP OVER PPP

GPRS is able to support all protocols that sit above IP. IP itself can be run over a wide range of lower level protocols, including radio bearer services such as GPRS.

The Point-to-Point Protocol, *PPP*, as operated widely across the Internet, is one of the simplest methods of working with IP over GPRS since the majority of modern operating systems support it.

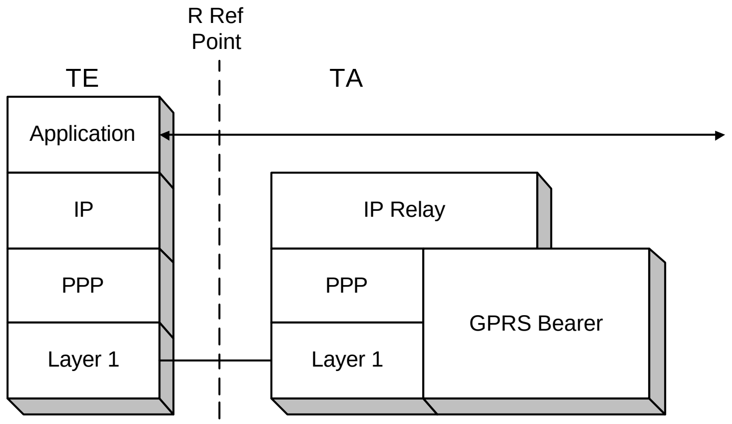

Figure 2 - Protocol Stack for IP Based Services

The GPRS device is a Terminal Adaptor (the terminology 'modem' is technically incorrect for all GSM/GPRS devices). It therefore provides an interface at the *R* reference point in the ISDN model of network access points.

Each interface at the R reference point can only support one PPP connection and each PPP connection can only host one IP session. The consequence is that only one PDP context can be activated per interface at the R reference point, whilst in PPP mode.

Section 9 describes the protocols used in the transmission plane in more detail.

3.1 Establishment Sequence

PPP is a Link Layer protocol. When IP over PPP is requested, the Link Control Protocol is set up between the TE and the ME. After this, the Network Control Protocol is negotiated and this includes communications across the radio link to attach the GPRS device and to activate the GPRS context.

The detailed sequence of messages that are exchanged between various elements in the system is not described here.

4. AT COMMANDS FOR GPRS

Most GSM Terminal Adaptors support a comprehensive range of AT commands based upon the GSM 07.07 technical specification. ETSI have based the command syntax around the V.250 (formerly V.25ter) guidelines and the command interface to a GSM TA is intended to meet the V.250 specifications.

Those AT commands specific to GSM are prefixed by '+C', where the '+' identifies it as an extended command and the 'C' is a reference to the Cellular nature of the GSM system.

The AT commands defined for GPRS begin with '+CG', where the 'G' stands for GPRS. GPRS is still a cellular based radio service.

Class-C GPRS devices, especially those that are only Class-CG, have limited, if at all, support for non-GPRS AT commands. The Mitsubishi Trium has more extensive support for GSM and GPRS AT commands that the Ericsson R320 and so responses to the examples listed below may differ from device to device.

A response of ERROR to any AT command probably means that the command has yet to be implemented in that device. Note that the prototype Ericsson handsets may respond with ERROR to an attach, even if the attach was successful.

4.1 Informative Examples

4.1.1 Querying the GPRS Device

This set of examples show some AT commands that can be issued without needing to attach to the service or activate a context. The responses presented by different devices may vary.

These are in addition to non-GPRS specific AT commands that are otherwise described in GSM 07.07.

Command	*AT+CGATT=?*	Query available attach states
Response	*+CGATT: 0, 1*	Can be detached or attached
Command	*AT+CGATT?*	Request current attachment state
Response	*+CGATT: 0*	Currently detached
Command	*AT+CGCLASS=?*	Query available classes
Response	*+CGCLASS: A, B, C, CG, CC*	List of available classes in descending order of functionality, as supported.
Command	*AT+CGREG=2;+CGREG?*	Request registration information
Response	*+CGREG: 2,1,"11AE","0003"*	Presents the <lac> and <ci> information
Command	*AT+CGSMS=?*	Query SMS options
Response	*+CGSMS: 0,1,2,3*	List of supported services

4.1.2 Mobile Initiated Context Activation

In this example, the TA begins in the normal V.250 Command State, i.e. AT commands can be entered. The command +CMEE has been issued so that any errors are reported with a diagnostic result code.

The GPRS AT commands are then issued in a verbose sequence to illustrate the processes involved in activating a GPRS context.

Command	*AT+CMEE=1*	Extended error reporting
Response	*OK*	
Command	*AT+CGDCONT=1,"IP"*	Define a context locally as cid=1, using IP as the PDP
Response	*OK*	
Command	*AT+CGATT=1*	Explicitly attach to the GPRS
Response	*OK*	
Command	*AT+CGACT=1,1*	Activate the context with cid=1
Response	*OK*	

Three discrete steps can be identified above:

- **Define** the PDP context
- **Attach** to the GPRS network
- **Activate** the PDP context.

It is not generally necessary explicitly to activate a GPRS context because the act of dialling the GPRS Service Code will automatically active the specified context if it is not already active.

In the above example, no <PDP_Address> was specified within the +CGDCONT command. The service will therefore assign an address within its range, provided this facility is available. The IP can be queried once the context is active;

Command	*AT+CGDCONT?*	Request context information
Response	*+CGDCONT: 1,"IP",,,0,0* *OK*	This method does not return the PDP_Address unless it was explicitly provided in the +CGDCONT command
Command	*AT+CGPADDR=1*	Request PDP_Address for cid=1
Response	*+CGPADDR: 1, "192.168.1.14"* *OK*	Assigned address is returned

4.1.3 Entering the Data State

There are two ways to enter the Data State in GPRS (analogous to making a call in circuit switched networks). A new command, +CGDATA, is provided which causes the MT to perform whatever actions are required to establish communication between the TE and the network. This includes activating one or more PDP contexts if none are already activated.

In addition, the Dial command (i.e. ATD) is maintained in the GPRS environment, as an alternative method to +CGDATA, to provide backwards compatibility with existing applications. This method will also activate one or more PDP contexts if none are already active.

Command	*AT+CGDATA="PPP",1*	Connect using PPP as the L2P and using context with cid=1
Response	*CONNECT*	
Ad-Hoc	*IP packets exchanged*	
	L2P call termination method	Call clear request as per L2P
Result	*NO CARRIER*	
Command	*AT+CEER*	Query call termination reason
Response	*+CEER: <xxx>*	Where <xxx> is a manufacturer specific report. Refer to TA documentation.

A special **GPRS Service Code** is defined with a value of '99', which identifies a request to use GPRS. Further parameters on the ATD command line are delimited by the asterisk character (*) and the command string is terminated with a hash (#). This syntax is specified in GSM 02.30.

The basic content for this parameter is *ATD*99***1#*, which will activate the specified context (1) pending further instruction.

Command	*ATD*99***1#*	Connect to GPRS service
Response	*CONNECT*	
Ad-Hoc	*IP packets exchanged*	
	L2P call termination method	Call clear request as per L2P
Result	*NO CARRIER*	
Command	*AT+CEER*	Query call termination reason
Response	*+CEER: <xxx>*	Manufacturer specific result code

4.1.4 Abnormal Call Clear

GPRS Attaches and active contexts can recover from the MS going briefly out of coverage, or from being subject to intermittent interference. However any communication in progress will of course be interrupted. It is up to the application to deal with, and recover from such interruptions in a sensible manner.

If the connection is lost at any time, the ME shuts down the PPP and it returns to the V.250 Command State. This is accompanied by the final result code *NO CARRIER*.

5. APPENDIX 1 – CONFIGURATION SETTINGS

A laptop PC can be provided with the following configuration settings for some (but not all) combinations of handset, connection and operating system.

- Modem definitions
- Dial-up Networking connections
- Reflection sessions
- Macro scripts
- Login Client configurations

Example settings for two handsets on Windows 98 are given below. Only those settings that have a value or must absolutely not have a value are listed. I.e. if a dialog box presents a checkbox and the box is not checked, the parameter will not be listed.

5.1 Modem and Dial-Up Networking Settings

The following settings are appropriate for Ericsson GPRS devices that use the Infrared port and Motorola T260 handset, connected directly to COM1 via a cable. As different combinations are tested, configuration files will be made available.

Table 5 - Modem and Dial-Up Networking Configuration Settings

Modem Settings		
Title	"Ericsson R520"	"Standard 33600 bps Modem"
General		
Port	Virtual Infrared COM port	Communications Port (COM1)
Maximum Speed	115200	57600
Connection		
Data Bits	8	8
Parity	None	None
Stop Bits	1	1
Cancel the call if not connected within	60 seconds	*Not specified*
Options		
Wait for credit card tone	8 seconds	8 seconds
Display modem status	SET	SET
Advance Port Settings		
	Default settings	Default settings
Advanced Connection Settings		
Flow Control	SET Hardware (RTS/CTS)	SET Software (Xon/Xoff)
Extra settings	*None*	*None*
Append to log	Optional but off by default	Optional but off by default
Dial-Up Networking Properties		
Title	"Ericsson DUN"	"Motorola"
General		

	Area codes are not used in GPRS. With the box "Use area code and Dialling Properties" unchecked, the Area code field is greyed out.	
Telephone number	*99***1#	*99#
Connect Using	Ericsson GPRS Prototype	Standard 33600 bps Modem
Server Types		
Type of Dial-Up Server	PPP: Internet Windows NT Server, Windows 98	PPP: Internet Windows NT Server, Windows 98
Record a log file for this connection	SET	SET
TCP/IP	SET	SET
TCP/IP Settings		
IP Address	Server assigned IP Address	Server assigned IP Address
Server Addresses	Server assigned name server addresses	Server assigned name server addresses
Use default gateway on remote network	SET	SET
Scripting and Multilink	These two pages have no customised settings, but for reference, no script files are defined or used. If you wish to define logon scripts for your own services, please do so in a copy of the Dial-Up Networking settings.	
Start terminal screen minimized	SET	SET

5.2 Reflection Session Configurations

For each device, a terminal session has been defined within the Reflection terminal application. These are used to issue necessary AT commands to the GPRS device prior to using Dial-Up Networking. The key difference between each session is that the correct device is chosen and operated at the correct speed. The macro for defining a context is identical for both cases.

Please do not change the settings for these sessions. If you wish to experiment with different settings, please do so on a copy of the session.

5.2.1 Custom Toolbar

To avoid having to remember the AT command strings, and to prevent the mistyping of them, three buttons have been added to the toolbar. One of these calls upon a macro, a sample of which is listed below.

The settings for the three customised buttons are as follows

Table 6 - Custom Toolbar Objects in Reflection

	Attach	Set IP address	Detach
Label	Attach	Set IP Address	Detach
Tooltip text	Attach	Define Context	Detach
Action	Send text	Macro	Send text
Text to send	*AT+CGATT=1<CR>*		*AT+CGATT=0<CR>*
Macro type		Visual Basic	
Macro Name		GPRSCon	

5.2.2 Macro Contents

This information is provided for reference (parameters may vary). The following macro performs three functions,

- Defines a suitable context to be activated later
- Requests a particular QoS level
- Specifies a minimum acceptable QoS level.

The QoS values are not fully implemented but the sequence provides an idea of a typical GPRS sequence.

The macro issues each of the AT commands and only continues if OK is received. Therefore, if there should be a problem and ERROR is returned, simply type 'AT' to solicit an OK response. The script should then run to completion, but it will be necessary to find out why the error occurred.

```
Attribute VB_Name = "NewMacros"
Sub GPRSCon() '' GPRSCon macro
Attribute GPRSCon.VB_Description = "Macro created 26/01/00 by gprsuser4"
' Macro created 26/01/00 by gprsuser4
'
    On Error GoTo ErrorHandler

    Dim username As String

    Const NEVER_TIME_OUT = 0

    Dim LF As String    ' Chr$(rcLF) = Chr$(10) = Control-J
    Dim CR As String    ' Chr$(rcCR) = Chr$(13) = Control-M

    LF = Chr$(rcLF)
    CR = Chr$(rcCR)

    username = Chr$(22) & CR
    With Session
        If .Connected = False Then
            .Connect
        End If

        ' .WaitForString Chr$(22) & CR, NEVER_TIME_OUT, rcAllowKeystrokes
        ' Press EditPaste (Insert the Clipboard contents at the cursor position).
        ' Reflection has recorded the record-time contents of the clipboard.
        ' If you want to use the playback-time contents of the clipboard,
        ' Uncomment the following line and delete the appropriate record-time
      data.
        ' Paste
        .Transmit "at+cgdcont=1,""IP"",""WWW.ERICSSON.SE"",""C0A80109""" & CR
        .WaitForString LF & "OK" & CR & LF, NEVER_TIME_OUT, rcAllowKeystrokes
        .Transmit "at+cgqreq=1,2,1,3,9,18" & CR
        .WaitForString LF & "OK" & CR & LF, NEVER_TIME_OUT, rcAllowKeystrokes
        .Transmit "at+cgqmin=1,2,1,3,9,18" & CR
        .WaitForString LF & "OK" & CR & LF, NEVER_TIME_OUT, rcAllowKeystrokes
        '
    Exit Sub

ErrorHandler:
    .MsgBox Err.Description, vbExclamation + vbOKOnly

    End With
    ' Recording stopped at 16:11:00.84.

End Sub
```

6. APPENDIX 2 - CONFIGURATION FOR VODAFONE GPRS CONNECTION SCRIPT

A script has been written for the Reflection terminal application to automate the attach and definition of context and Quality of Service parameters for a GPRS handset. It may also be used to detach from the service when all activity is complete.

6.1 How To Use

A shortcut titled **GPRS Connection Script** has been placed on the desktop to allow a GPRS handset to be attached or detached from the service. (If it is already attached, a detach will be performed and vice-versa).

Double-click on the icon to run it. The session will run in a minimised state and will remain hidden from view until it has finished. A dialog box will indicate success or failure of the script.

If attaching a device, once the script has finished, Dial-Up Networking can be used to establish a connection across the GPRS.

Once the Dial-Up Networking session has been disconnected, this script should be run again to detach the device from the service.

The script is flexible and can be configured to work with a wide range of handsets. This means that as new handsets become available, the script should still be able to be used (configuration settings will need updating).

6.2 Location of the Files

A shortcut should reside on the desktop to facilitate access to the service.

The standard location for Reflection scripts is the 'User' folder as shown in the settings, below.

The default location of the configuration file is the root of the C: drive. This can be altered from within the script.

If the script file is not found, it will be created based upon settings requested of the user.

6.3 Shortcut on the Desktop

The script is activated from a shortcut on the desktop. The shortcut must be setup with the following parameters, where paths should be amended as required.

```
Target: "C:\Program Files\Reflection\r2win.exe" /N /RBS "C:\Program
      Files\Reflection\User\Gprs\Attach.rbs"
```

Where:

"C:\Program Files\Reflection\r2win.exe"	Points directly to the executable Reflection application
/N	Prevents Reflection splash page from being shown
/RBS "C:\Program Files\Reflection\User\Gprs\Attach.rbs"	Path to the script

Additional settings:

Run: Minimized or **Normal**	Hide or show the session, as desired.

6.4 Progress Indications and Script Behaviour

The script can either run completely silently or with the Reflection session window open so that the AT commands and their responses can be observed. This may help with understanding the nature of any problems that may occur. A parameter in the configuration file, **Show Progress**, can be either True or False to enable or disable this feature.

When the actions of the script have finished, the COM port is released so that other programs, such as Dial-Up Networking, can be used.

The script may also be configured to close Reflection completely when done. The configuration parameter **Exit When Done** controls this. If the parameter is set to False, Reflection remains open (but disconnected). The connection may be re-established so that AT commands can be entered to the device if desired.

6.5 The Configuration File

Path: C:\GPRSCon.cfg

Vodafone may redistribute this file from time to time as new handsets become available and if new Modem types are defined to use them.

```
# Vodafone GPRS Connection Script Parameters
# This configuration file is used by the Reflection script 'Attach.rbs' and contains
# parameters that may be changed if necessary.
# Deleting Essential lines of configuration will cause the script to request new values.
# Essential configuration parameter values can be empty to ignore that parameter altogether
Context=1
APN=WWW.ERICSSON.SE

# The IP Address should be in decimal format.  Will be converted to hex if necessary.
IP Address=192.168.1.1

# The Context ID in the parameters below does not have to match the Context value above.
AT+CGQREQ=1,0,0,0,0,0
AT+CGQMIN=1,0,0,0,0,0
# End of Essential configuration parameters.
Def QOS=1,2,1,3,9,18

# This parameter keeps the Reflection window open so that progress can be reviewed.
Show Progress=True

# By default, the Reflection session will terminate when complete.
Exit When Done=False

# List of known handsets: 'Result of ATI0-9 command','Format specifier for IP addresses'
# If ATI is not supported or handset not listed, 'dec' is assumed.
# Attach Options (one of): AD=Alternate Attach/Detach; AA=Always Attach
# QOS Options (one of): ConfigQOS, DefaultQOS, AskForQOS
# Must also specify which AT parameters require Quotes; PDP Type, APN, PDP Address
HANDSET=GSM DATA CARD MITSUBISHI ELECTRIC V.4.021 BETA,hex,AD,ConfigIP,
AskForQOS,QUOTES,QUOTES,QUOTES
HANDSET=Ericsson GPRS Prototype Modem,dec,AA,ConfigIP,AskForQOS,NOQUOTES,QUOTES,QUOTES
HANDSET=R520m Infrared Modem,dec,AD,ConfigIP,AskForQOS,NOQUOTES,QUOTES,QUOTES

# List of modems defined in Control Panel that GPRS devices will use.
# COM ports can also be listed as available.
MODEM=Generic Infra Red Device,COM4
```

Lines highlighted in **Bold** are considered 'essential' configuration elements. If these lines are not found, suitable values for them will be requested of the user.

It is valid for a line to have no value, e.g. "IP Address=". This will mean that no value will be specified in commands that might take that argument as a parameter. The IP address in this sample is an example only. Only the address allocated should be used.

If there are no Modem types, a connection at 38400 baud, 8 bits and no parity will be set up on COM1. All COM port connections are set up at 38400 baud with a parity of 8/None.

6.5.1 Resetting The Config File

If the script does not appear to be specifying the correct settings, e.g. the APN is wrong or missing, the config file has probably been amended incorrectly.

The best way to sort things out is to reset only that part of the configuration that has a problem.

- Open the file in a text editor, such as Notepad
- Delete only the line in question, e.g. the whole line that says "APN=…"
- Save the config file and quit the editor
- Restart the script

The parameter should be requested if it is an essential parameter.

6.5.2 Manual Modifications

Manual modifications to the config file are allowed. For instance, the parameters "Always Attach" and "Use Default QOS" are manual override settings. These parameters take True or False as their argument.

Also, new handsets and their required modem types must be added manually, as per the template and examples.

6.6 Flowchart

The sequence of actions for the script is described by the flowchart, below. It is possible to hide the action of the script by changing the "Show Progress" parameter to False.

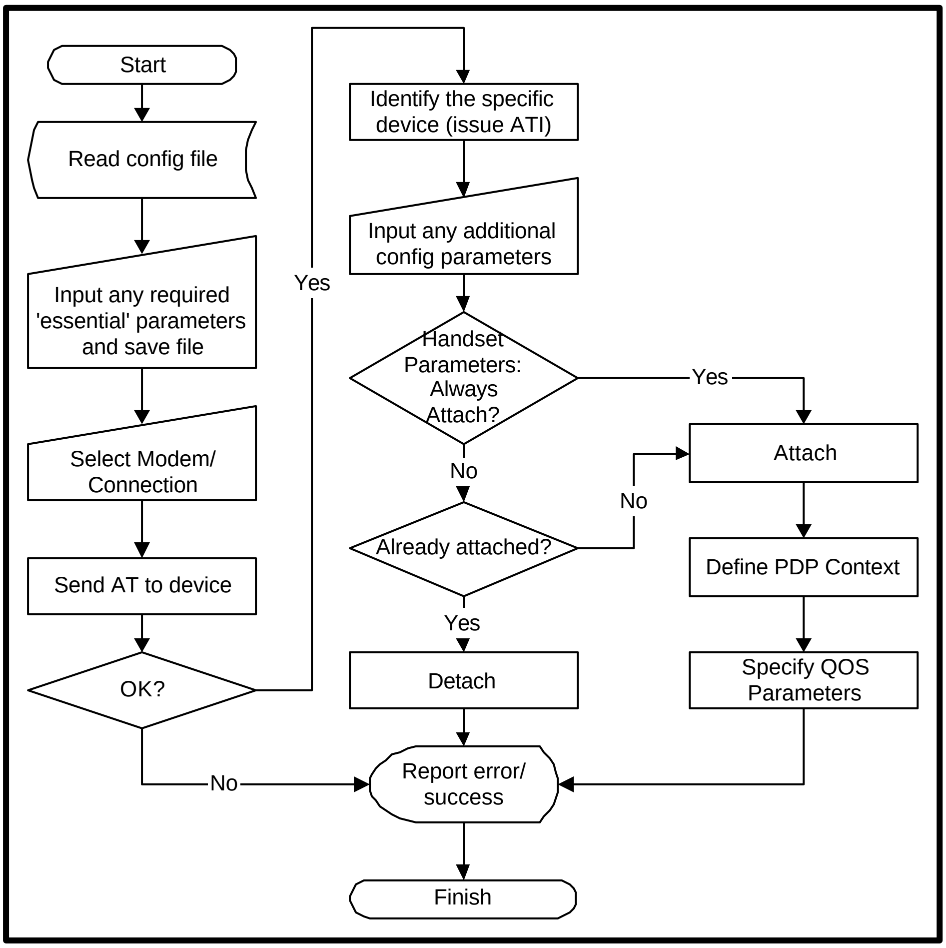

Figure 3 - Flowchart for GPRS Connection Script

If the config file is missing all of the "essential" parameters, these will be requested. The file will then be saved.

It is necessary to choose a connection mode so that the device can be tested. The modem and connection types are specified in the config file, although COM1 is always available.

Once connected, the script will check to see if the device is present by issuing AT. It will timeout after a few seconds if nothing is detected and report an error.

The ATI command is executed next to detect the identity of the device attached. ATI0 to ATI9 are issued in sequence until a match is found to a defined handset. If no match is found, a series of default parameters are assumed.

Some of the earliest GPRS handsets had limited support for GPRS AT commands. A parameter, "Always Attach", can be specified for certain devices, such as the Ericsson R320 Prototype, to override the normal action of this script. If the parameter is False, the script will attempt to perform an attach if the device is currently detached and vice-versa.

Most of the configurable handset parameters are applied during the definition of the PDP context. The APN and IP address are taken from the configuration parameters and some parameters may need to be enclosed in double quotes. Furthermore, some devices require the IP address to be in decimal format and others require this to be in hexadecimal. The script will take care of all of these requirements on a per handset basis, if configured to do so.

When the script has finished executing, the session will terminate completely if “Exit When Done” is True. If this configuration parameter is False, the Reflection session will remain open but in a disconnected state. In this way, Dial-Up Networking can be used, or the session can be reconnected to allow AT commands to be typed manually.

6.7 Handset Definitions

The syntax requirements of each handset may vary and the configuration file can reflect these requirements. A handset definition may look as follows:

```
HANDSET=<ATIn Result>,<IP Mode>,<Attach Options>,<IP Options>,<QOS
      Options>,<Quotes?>
e.g.
HANDSET=R520m Infrared Modem,dec,AD,ConfigIP,AskForQOS,QUOTES,QUOTES,QUOTES
```

Where;

<ATIn Result>:	A suitable descriptive result from any of ATI0 to ATI9
<IP Mode>:	“hex” or “dec” for format of IP address in +CGDCONT. Must be the parameter immediately after <ATIn Result>
<Attach Options>:	AD=Alternate Attach/Detach; AA=Always Attach
<IP Options>:	ConfigIP=Use the IP address in the Essential parameters section; AskForIP=Override the IP address in the Essential Parameters with a value requested of the user.
<QOS Options>:	ConfigQOS=Use the QOS string in the Essential parameters section; DefaultQOS=Use the default QOS string for both +CGQREQ and +CGQMIN commands; AskForQOS=Override the stored QOS values with a string requested of the user.
<Quotes>:	A list of **three** flags to identify if double quotes (“) must be placed around certain parameters in the +CGDCONT command. The parameters that may require quotes around them are: PDP Type (e.g. IP); APN Address (e.g. WWW.ERICSSON.SE); PDP Address (e.g. 192.168.1.x). The handset definition requires a value of QUOTES or NOQUOTES.

6.7.1 Adding A New Handset

As new handsets become available, the configuration options described above can be specified to allow that handset to operate correctly with this script. A small amount of preparation is required first to determine the correct settings. This preparation involves typing the AT commands manually to find out the syntaxes of the various commands.

The steps are as follows

1. Open the file C:\GPRSCon.cfg in Notepad so that details can be recorded as they are determined. In the section where the handsets are located, add a new line and enter the text **HANDSET=**
2. If the handset is supplied with a modem configuration file, install this.
3. Open a Reflection session and attempt to communicate with the device. Select a defined Modem type or choose the COM port to which the handset is connected. For COM ports, the speed (try 38400) and parity (use 8/None) should also be selected.
4. Type **AT** and look for the OK response. If nothing is seen, return to step 3. and choose different settings until OK is seen to the AT command.
5. Get the Modem Information string. Type **ATI0** (ATI Zero) and hit return. If what is returned seems to suitably describe the handset, copy the string into the clipboard, then paste it after the Equals sign on the new HANDSET line in GPRSCon.cfg. If ATI0 did not provide a suitable response, try **ATI1** (ATI One) then **ATI2** up to **ATI9** until an acceptable response is found.

6. Next it is necessary to identify whether the handset requires IP addresses to be in decimal or hexadecimal format. This parameter must be the next parameter after the Modem Information string. Unless you know otherwise, just enter **,dec** for now (where the comma is used to separate this field from the one before)

7. Type the AT command *AT+CGATT?* And note the response. If the response is *+CGATT: 0* or *+CGATT: 1* then the next parameter on the HANDSET= line should be *AD*. If either of these responses is not observed, type *AA*.

Response to AT+CGATT?	Attach Option
+CGATT: 0	*AD*
+CGATT: 1	*AD*
Anything else	*AA*

The next two parameters, <IP Options> and <QOSOptions> are up to the user. If the values for these parameters within the configuration file are always going to be correct, these can be set to *ConfigIP* and *ConfigQOS* respectively. If they will constantly vary, set them to *AskForIP* and *AskForQOS*. The Quality of Service options have an additional parameter that allows a default value to be used, *DefaultQOS*.

8. The final set of parameters can only be obtained through trial and error. Try the following permutations of parameters until the handset responds with OK. Then add the parameters to the HANDSET= line as shown. For example, AT+CGDCONT=1,"IP","WWW.ERICSSON.SE","1.2.3.4"

	Arguments to AT+CGDCONT=	Add this to line in GPRSCon.cfg
1	*1,"IP","WWW.ERICSSON.SE","1.2.3.4"*	*QUOTES,QUOTES,QUOTES*
2	*1,IP,WWW.ERICSSON.SE,1.2.3.4*	*NOQUOTES,NOQUOTES,NOQUOTES*
3	*1,IP,"WWW.ERICSSON.SE","1.2.3.4"*	*NOQUOTES,QUOTES,QUOTES*
4	*1,"IP",WWW.ERICSSON.SE,"1.2.3.4"*	*QUOTES,NOQUOTES,QUOTES*
5	*1,IP,WWW.ERICSSON.SE,"1.2.3.4"*	*NOQUOTES,NOQUOTES,QUOTES*
6	*1,"IP","WWW.ERICSSON.SE",1.2.3.4*	*QUOTES,QUOTES,NOQUOTES*
7	*1,IP,"WWW.ERICSSON.SE",1.2.3.4*	*NOQUOTES,QUOTES,NOQUOTES*
8	*1,"IP",WWW.ERICSSON.SE,1.2.3.4*	*QUOTES,NOQUOTES,NOQUOTES*

9. If all of these permutations respond with an **ERROR** it may be because the IP address must be in hexadecimal format. Repeat the series of arguments as follows until OK is received.

	Arguments to AT+CGDCONT=	Add this to line in GPRSCon.cfg
9	*1,"IP","WWW.ERICSSON.SE","01020304"*	*QUOTES,QUOTES,QUOTES*
10	*1,IP,WWW.ERICSSON.SE,01020304*	*NOQUOTES,NOQUOTES,NOQUOTES*
11	*1,IP,"WWW.ERICSSON.SE","01020304"*	*NOQUOTES,QUOTES,QUOTES*
12	*1,"IP",WWW.ERICSSON.SE,"01020304"*	*QUOTES,NOQUOTES,QUOTES*
13	*1,IP,WWW.ERICSSON.SE,"01020304"*	*NOQUOTES,NOQUOTES,QUOTES*
14	*1,"IP","WWW.ERICSSON.SE",01020304*	*QUOTES,QUOTES,NOQUOTES*
15	*1,IP,"WWW.ERICSSON.SE",01020304*	*NOQUOTES,QUOTES,NOQUOTES*
16	*1,"IP",WWW.ERICSSON.SE,01020304*	*QUOTES,NOQUOTES,NOQUOTES*

10. If a hexadecimal IP address was necessary, modify the dec parameter after the Modem Information string to **hex**.

7. APPENDIX 3 – GPRS SPECIFIC AT COMMANDS

This section provides a summary of the AT commands that have been defined for GPRS. They are fully described in GSM 07.07. Support for these commands within devices is likely to be extended as the functionality is achieved.

There are two types of action command: those that are associated with parameters that may be able to be set, read and tested, and those that are not.

To **set** the value, the command is followed by an equals (=) sign and a list of parameters compatible with the syntax of the command, e.g. *AT+CGATT=1*

The current value is **read** by appending a question mark (?) to the command, e.g. *AT+CGATT*?

The range of acceptable values can be **tested** by appending the command with '=?', e.g. *AT+CGATT=?*

7.1 GPRS AT Commands

Table 7 - Summary of AT Commands for GPRS

Command	Description
+CGACT	PDP context activate or deactivate
+CGANS	Manual response to a network request for PDP context activation
+CGATT	GPRS attach or detach
+CGAUTO	Automatic response to a network request for PDP context activation
+CGCLASS	GPRS mobile station class
+CGCLPAD	Configure local triple-X PAD parameters
+CGDATA	Enter data state
+CGDCONT	Define PDP context
+CGEREP	Control unsolicited GPRS event reporting
+CGPADDR	Show PDP address
+CGREG	GPRS network registration status
+CGQMIN	Quality of service profile (minimum acceptable)
+CGQREQ	Quality of service profile (requested)
+CGSMS	Select service for MO SMS messages

Table 8 - Summary of Existing GSM AT Commands with GPRS Extensions

Command	Description
+CEER	Extended error report (refer to 07.07)
+CMEE	Report mobile equipment error (refer to 07.07)
+CR	Service reporting control (refer to 07.07)
+CRC	Cellular result codes (refer to 07.07)

Table 9 - Summary of AT Commands for GPRS Modem Compatibility Mode

Command	Description
A	Answer - manual acceptance of a network request for PDP context activation
D	Dial - request GPRS service
H	On-hook - manual rejection of a network request for PDP context activation
S0	Automatic answering control - automatic acceptance of a network request for PDP context activation

8. APPENDIX 4 – THROUGHPUT CALCULATIONS

Section 1.6 introduced the way bandwidth is allocated and utilised in GPRS. The table in that section listed the maximum data rate per Coding Scheme when one to four channels are used. The user data rate (payload data) is always going to be less than this because of the overhead introduced by all of the necessary protocols. Since packet sizes vary, and given that GPRS is specified to be used with a number of different Layer 2 Protocols it is not possible to list a single user data rate to meet all requirements.

This section provides some examples of data rate calculations with respect to typical uses. GPRS uses much of the same infrastructure as GSM and so is bound by some of the design decisions behind that technology, so a brief introduction to some relevant aspects of GSM is provided.

8.1 GSM and the Air Interface

The basic data rate for most digital networks is 64Kbps (K bits per second – NB. bits, not bytes). This figure is arrived at through sampling theory in the following manner.

The human ear can detect sounds in the range of a few hundred Hz up to around 20KHz, but most of the frequencies required to recognise human speech are in the range between 300Hz and 4000Hz. This requires the voice to be sampled 8000 times per second. Each sample is quantised to one of 256 values, requiring 8 bits of data per sample. Hence, 8000 samples per second x 8 bits per sample = 64Kbps.

This data rate is fine for PSTNs, where bandwidth is not too much of an issue and error rates are also not so consequential. However, the air interface is a far more limited resource and is much more difficult to work with. GSM employs coding schemes optimised for voice that provide compression and forward error correction. This coding scheme takes samples of speech 20ms in length and turns them into a **Radio-Block** of **456 bits**. The Radio-Block is sent in four bursts across successive timeslot periods, along with additional bits of information required by the air interface.

Each cell in the GSM frequency spectrum provides enough capacity for one control timeslot and seven full-rate voice timeslots, i.e. the air bandwidth is time-division multiplexed eight ways.

The result is reasonable, albeit not perfect, speech reproduction that is acceptable for a wide variety of applications.

8.2 GPRS Data

GPRS is an extension to GSM and uses the same frequencies, air interface protocols and in many cases, the same cells as GSM. Therefore, the Coding Schemes applied in GPRS must fit the GSM model.

The **GPRS Radio-Block** is also 456 bits, as in GSM, and the four GPRS Coding Schemes manipulate the user data to fit this structure. The payload of the Radio-Block includes any higher level protocol overheads, e.g. RLC and TCP/IP headers and these will be examined further on. Table 10 shows how much data can be contained (maximum) within each Radio-Block per Coding Scheme. RLC is the Radio Link Control protocol and has an additional header that is not included in the figures below.

Table 10 - RLC Data Unit Capacity Per Radio-Block for CS1 to CS4

	CS1	CS2	CS3	CS4
Bits	160	240	288	400
Bytes	20	30	36	50

RLC introduces its own overhead, from which the maximum theoretical data rate for each coding scheme is derived. The RLC data unit size plus overhead are divided by 20ms to give this total data rate per timeslot. The effective data rate per timeslot is found by dividing the RLC Data Unit by 20ms. These figures can be found in Table 11.

Table 11 - Derivation of Data Rates Per Timeslot for Each Coding Scheme

	CS1	CS2	CS3	CS4
RLC Data Unit (bits)	160	240	288	400
RLC Overhead (bits)	21	28	24	28
Total (bits)	181	268	312	428
Data Rate (Kbps)	9.05	13.4	15.6	21.4
Effective Rate (Kbps)	8.00	12.0	14.4	20.0

The Radio-Block is sent in four bursts in exactly the same way as if it were a GSM block containing voice data. A Packet Control Unit (PCU) at the Base Station will decide if the data is a GPRS packet, in which case it will be sent to the SGSN, or a GSM voice call, in which case the call will be routed via the GSM network.

In order to determine how many Radio-Blocks are actually required to transmit a given quantity of data, and to identify how much of the overall payload is taken up by overhead from intermediate protocols, an example working from the other direction will be considered.

8.3 GPRS Data Coding Example

Suppose 1000 bytes of HTTP or FTP data are to be sent to a GPRS handset. There are several layers of protocol that need to be added to this payload of data before we get to the radio path. The size of each header is shown in Table 12 and all layers are applied for TCP/IP transmission over PPP.

Table 12 - Protocol Overheads Added to User Data

Protocol	Overhead
TCP	24
IP	20
SNDCP	4
LLC	7
Total	55

This means that of our 1000 bytes of data, 1055 bytes need to be incorporated into RLC data units. This determines how many Radio-Blocks will be needed, rounded up to the nearest whole block.

Table 13 - Number of Radio-Blocks Required for a 1000 Byte Sample of Data

	CS1	CS2	CS3	CS4
User Data (bytes)	1000	1000	1000	1000
Total Data (bytes)	1055	1055	1055	1055
RLC Data (bytes)	20	30	36	50
Radio-Blocks Required	53	36	30	22

The maximum average user data rate attainable, assuming Coding Scheme 1 and assuming that we are the only user on the cell for the duration of this transmission, is 7.54 Kbps for this transmission. This is worked out as follows;

The total data rate for CS1 is 9.05Kbps for the whole RLC Data Block (181 bits), of which 160 bits are from the RLC Data Unit. Hence, 160 bits divided by 20 ms yields 8.00 Kbps, providing an *effective* data rate.

The average user data rate is therefore the ratio of how much data the application layer thinks is being transmitted to how much data is actually being transmitted, multiplied by the effective data rate.

The amount of data actually transmitted is the total payload of all of the Radio-Blocks, even if they are not all fully utilised. In CS1, the Radio-Block has an effective payload of 20 bytes and when multiplied by the number of blocks required yields 1060.

```
                        1000 bytes
Mean User Data Rate =  ------------  x  8.00 Kbps = 7.54 Kbps
                        1060 bytes
```

It will take a minimum of 0.966 seconds to transmit this data across the air interface. This is obtained by dividing the effective data rate by the total amount of data.

```
                            8.00 Kbps x 1000
Minimum Time To Download = ------------------ = 0.966 seconds
                             1060 bytes x 8
```

Generically, if D is the amount of data being sent, N is the number of Radio-Blocks required, P is the maximum payload of the Radio-Block and E is the effective data rate for the Coding Scheme being used then the average user data rate, R, is determined as follows

```
               D [bytes]
R [Kbps] =  ---------------  x  E [Kbps]
             N x P [bytes]
```

Where, if O is the overhead introduced by all applicable protocols (55 bytes in this case);

```
     D + O
N = ------- Rounded up to the nearest whole number.
       P
```

The effective data rates for each Coding Scheme can be found in Table 11.

If more than one timeslot is utilised, multiply R by the number of timeslots in use at any given time.

It should be noted that maximum throughput levels are only possible if a device is the only effective user of the GPRS cell at that time. If more than one user is transmitting or receiving at the same time, the bandwidth is shared between all effective users. However, if the traffic profiles are bursty then there is a reasonable probability that your transmission will be in a period when other users are silent.

Finally, if a separate utility is used to monitor the data rate as received by the PC, values much higher than the limits described here may be observed. This is because the GPRS device has received its Radio-Block over a 20ms period and buffered it until the whole Radio-Block has been received. The data is then transmitted across the serial or Infrared link at the negotiated speed for that link, which may be significantly higher. For example, 161 bits of data might be transmitted in 7ms, yielding a brief data rate of 23Kbps. This figure is for example only.

9. APPENDIX 5 – GPRS NETWORK ARCHITECTURE

This section details the components of the GPRS network and the interfaces to other networks and services. The protocol stacks across the network are also described.

9.1 The GPRS Network

The two key elements in the GPRS network are the SGSN and the GGSN. These form the backbone of the network and provide the interfaces to other systems, such as the Base Station System (BSS), and external networks, such as the Internet.

The SGSN is the Serving GPRS Support Node and manages the attaches and contexts of remote GPRS devices. The GGSN is the Gateway GPRS Support Node and provides the access points to external networks. In the Vodafone GPRS network the SGSN and GGSN are implemented together as a CGSN (Combined GPRS Support Node).

Each link in the system is given a label for reference. Um is the air interface, Gb is the GPRS Base Station link, Gn links connect the support nodes together and Gi links provide access to external networks such as the Internet.

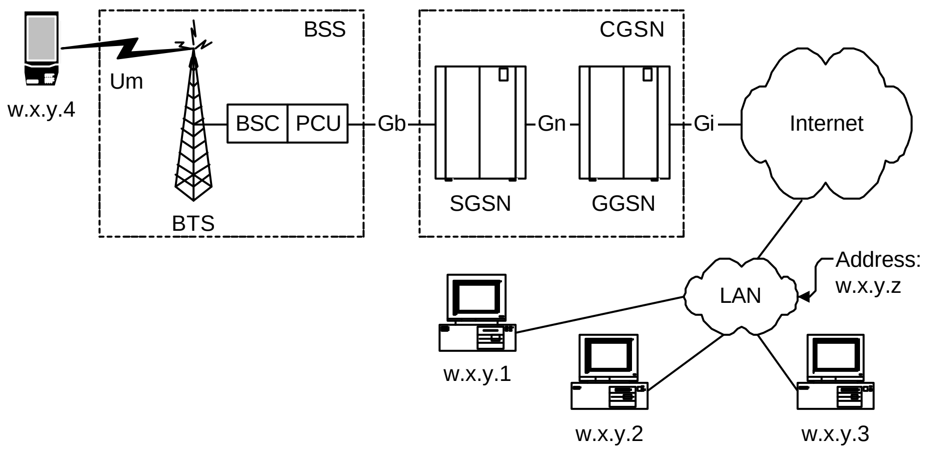

Figure 4 - The Basic GPRS Network

Figure 4 shows a remote LAN to which connectivity is made. The LAN has its own IP sub-address and every terminal on that LAN has a unique number within that range, e.g. w.x.y.1, w.x.y.2 and so on.

GPRS enables the roaming user to have a point of presence on that LAN, firewalls etc. permitting. I.e. the GPRS handset will have an IP address with the same sub-address as the fixed terminals on the network, e.g. w.x.y.4.

The Vodafone GPRS Development Environment that has been set up by Vodafone is intended to represent a LAN belonging to the end user and will not be used to provision IP addresses beyond the scope of a test and demonstration network.

9.2 Protocols in the Transmission Plane

In section 8 a stack of protocols was introduced that are applied to data travelling across the air interface. Additional protocols are applied throughout the network to make the data readable by the destination and these are described in Figure 5. Ultimately, the user data must be encapsulated by the correct Layer 2 and PDN protocols so that the data can be extracted however it is not necessary to apply these protocols across the air interface, thereby conserving bandwidth.

Figure 5 describes the protocols for an end-to-end TCP/IP transmission from the TE all of the way to a terminal on the destination LAN. The SGSN and GGSN use TCP/IP to communicate with each other and the user data is hidden within this packet using a Gateway Tunnelling Protocol (GTP). This is especially important since the PDP type may not be IP.

The GGSN is responsible for applying the correct layer 2 (PPP) and layer 3 (IP) protocols so that the fixed terminal has no direct knowledge that the packet originated on a GPRS network.

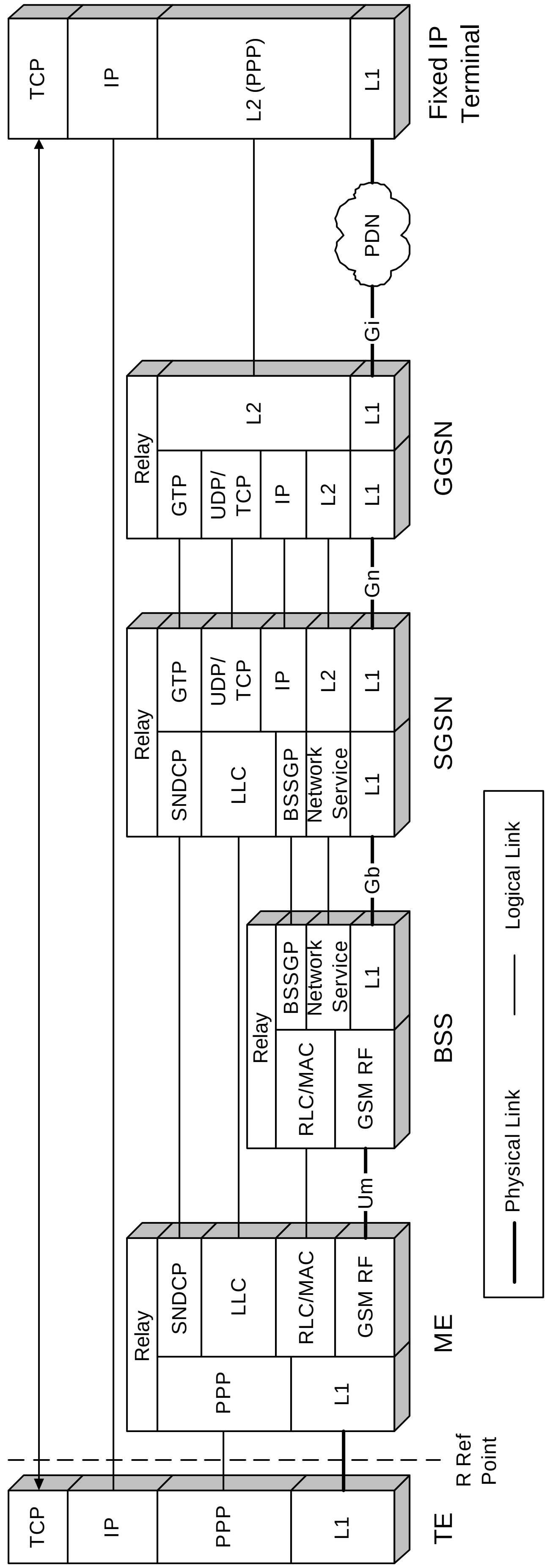

Figure 5 - GPRS Transmission Plane