VIGIE: A Learning Tool for Cellular Air Interfaces (GSM, GPRS, UMTS, WiFi)

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Abstract—*One of the difficulties encountered in the teaching of mobile radio networks is to present in a simple way the interaction and the sequencing of various tasks, which must be carried out by the mobile station (MS) and the network over the air interface. The comprehension of these processes is facilitated when they are presented in a visual form that can be understood in real-time, when the common MS-Network tasks such as voice call (MS oriented or MS terminated), short message service (SMS) are going on. This paper describes the architecture of the VIGIE (Visualisation and Interpretation of GSM/GPRS for Institutes & Ecole) software, developed in Java to display the exchanges of these tasks between the MS and the network. The uniqueness in the architecture of this tool is revealed in terms of its modularity. Finally the current work done on the development of the General Packet Radio Service (GPRS) logical screen and the Downlink Signaling Counter (DSC) graphical screen are described*

Index Terms—*Air interface, GPRS, and GSM*

1. INTRODUCTION

BETWEEN 1996 and 2000 a software tool for the teaching and visualization of Global System for Mobile Communications (GSM) protocol over the air interface called GSMShow was developed within the department of Information and Networks of ENST (Ecole National Superieure des Telecommunications). This software is used on a computer connected via a serial link to a *GSM trace mobile*. A trace mobile is similar to an ordinary mobile station in every aspect and can be used on any operational network except that it has the characteristic to send in "rough form" (a succession of bytes) the messages exchanged between the network and its measurements and calculations. The role of this software is to display in a convivial form the exchanges between the network and the trace mobile. The user thus sees the exchange of these frames but from different points of view; each point of view is what led to the development of different windows where the user can monitor specific behavior of the mobile to the network or vice-versa. In 2001, the advent of GPRS led to the development of a new software tool called VIGIE. This software was developed by ENST-Paris and ENST-Bretagne. VIGIE is a teaching aid particularly adapted to render comprehensible, the principle of encapsulation (joint visualization of layers 2 and 3), frequency hopping, management of *timing advance* (TA) and power control, logical channels , activation of GPRS sessions and so on. It also makes it possible to highlight the sequencing of messages for various services. This software is developed in Java, and the the aim is to make it more evolutional than its predecessor (GSMShow). It is able to support the GSM/GPRS protocol and also to be interfaced with, potentially any trace mobile. In the future, it will be able to support other protocols such as *Wireless Local Area Network* (WLAN), *Universal Mobile Telephone Service* (UMTS) or *Enhanced Data rates for GSM Evolution* (EDGE).

2. PRINCIPLE OF OPERATION

2.1 Review Stage

The VIGIE software is intended to be used coupled with a trace mobile, which is connected to the computer via a serial link. The trace mobile theoretically allows the retrieval of all signaling frames as well as frame headers of transmitted data during communication. It also transmits information about the radio environment where it operates and in particular reception measurements levels of signals transmitted by the neighboring cells.
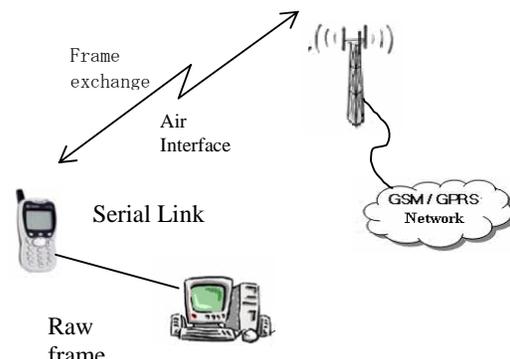

Figure 1: Sequential connection of entities interacting during the use of VIGIE software

The information transmitted by the mobile on the serial link is generally divided into two parts:

the information transmitted by the mobile, which has a format that is actually dependent on the type of trace mobile used[9] and on the other hand the standardized frames which are transmitted or received on the radio link. However the reception of these frames is useful only if the user is able to understand and interpret them. This binary format is not very convivial and does not emphasize on the most significant aspects of the radio resource procedures. VIGIE thus makes it possible to automate this decoding, to interpret the frames contents and most importantly to have the results in such order that will facilitate the user to understand the operation of GSM/GPRS system.
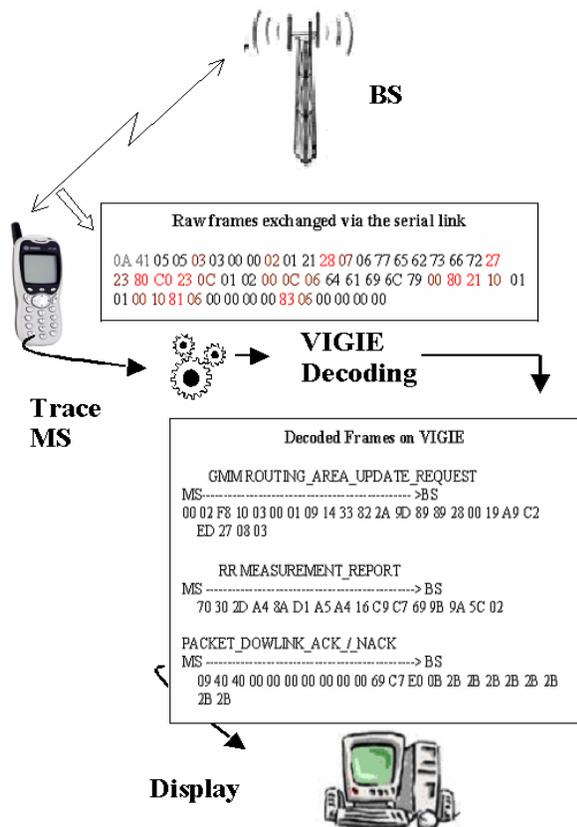

Figure 2: VIGIE principle of operation [5].

2.2 Functionalities

The VIGIE software consists of three modes of operation. The *serial mode* requires the serial connection of the trace mobile to the computer. In this mode, the software stores all the data (frames and reports) delivered by the mobile of trace in real time and records them in a temporary file, this is done to save all the data for possible future storage so as to re-launch the saved data for analysis.

The file mode *step-by-step* allows to run the recorded traces that were saved in the serial mode. Each time the user prompts, the message is read from the trace file; this mode is recommended if sequence of a specific task is to be closely monitored. The *fixed time delay* file mode is similar to the step by step file mode, except that the reading of the file is done automatically at the rate of 1 second.

3. SOFTWARE ARCHITECTURE

GSMShow, which is the predecessor of VIGIE interfaces only with the trace mobiles using *Orbitel* serial link protocol and as a result could not support the GPRS mobile radio protocol. It would have been very difficult to develop and add a new screen that will permit the display of GPRS system information.

Thus the architecture of VIGIE was conceived to be strongly evolutionary. It must be able, via a system of drivers to adapt to the protocol used by the trace mobile to communicate with the computer. It must also be able to present other mobile radio protocols such as the EDGE and UMTS or the operation of WLAN systems.

The data frames are conveyed between the trace mobile and the computer via the *serial link* (see figure 3) which interfaces the trace mobile with the computer. The format of the frames on the serial link depend on the trace mobile used but a system of *drivers* makes it possible to translate the incoming frames into a format we referred to as *generic.* That format can be used by all the remaining modules within the software architecture. The driver primarily makes it possible to group raw frames captured by the mobile into two main groups; the information received from the network such as those transmitted on the logical channels and the results of the measurements the mobile carried out to report back to the network: we referred to these formats as the *Frame* and *Report* respectively. We also further identifies *Report* types (idle mode or dedicated mode) and frame type - layer 3 (L3), GSM layer 2 (L2), GPRS, and GPRS Mobility Management – Session Management (GPRS GMM-SM). As shown in figure 3, it is the generic format that is temporarily saved, which means that it is impossible to view the raw frames coming directly from the trace mobile in the step-by- step mode. Thus the appearance of a new type of trace mobile requires only the creation of the driver that corresponds to such trace mobile. The generic frames are presented in the form of Java serializable objects, which makes it possible to be recorded in a file format (in this case we used *.trc* extension) in order to re-launch the saved trace when data to be observed is not in real time mode.

A module we referred to as the *Interpreter* makes it possible to further carry out decoding of

the frames and report. The interpreter decodes the content of L3 frames and sort them using protocol discriminator into *call control* (CC), *mobility management* (MM), *radio resource* (RR), *session management* (SM) messages, *radio link control / medium access control* (RLC/MAC) messages. The sorting of messages sent on the logical channels, which include *slow associated control Channel* (SACCH) data, *broadcast control Channel* (BCCH) report, page report, channel request report, *access grant control channel* (AGCH) report and synchronization report are done by the interpreter.

The *Dispatcher* makes it possible for the decoded frames and reports in idle and dedicated mode to be progressively distributed as required onto each window upon their arrival. It allows us to group together the frames, reports and to display them in a manner that can be easily understood.

The *Window* module represents viewing of different parameters/information as sorted by the Dispatcher; this is the graphic user interface part of VIGIE, where the users actually interact with the tool. A collection of windows may be considered as a module but they are independent of each other, again the modularity of this tool is being revealed in this aspect as a new window may be developed depending on what is intended to be displayed to the users.
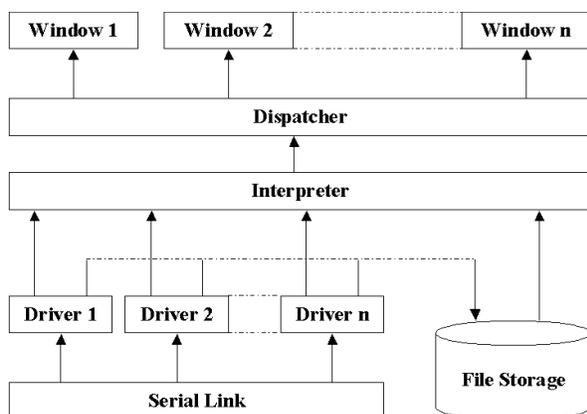

Figure 3: Simplified software architecture for VIGIE.

4. SOFTWARE DESCRIPTION

On the main GUI (Graphical User Interface) window there are eight different menus that can be activated (though more could be activated as we develop new screens). On top of this window, just below the menus, appears a horizontal bar that displays all the activities performed by the mobile (measurements, transmission or reception of frames). At the leftmost base of the main window is the *indicator of state*, which gives the state of connection of the trace mobile to the

serial ports; this could be *connected*, *not connected* or *disconnected*. Note that only the connected state is displayed when you are in the serial mode.

Description of the windows: The *Frame serial* window displays all the frames that are exchanged on the serial link in the raw format. This window is only active when you are in the serial mode. *Frames and Reports* window displays the decoded frames in generic format; this window is also active in the serial mode.

Dedicated Layer 2 and SACCH window displays all the layer 2 messages on the dedicated channel or on the SACCH.

GSM Layer 3 Message window displays the messages of layer 3 with or without filtering. Messages that can be filtered include BCCH System Information, Padding Paging, measurement Report, SACCH system Information, Paging (all types) and Empty.

Current BTS (Base transciever station) Configurations window displays various information of the current cell. If one of the neighboring cells is displayed in blue, this means that the BCCH message is being received at this frequency. In the same way display in green indicates the reception of synchronization message. The edge of the box indicates the state of the mobile; if displayed in blue, the mobile is in idle mode while red indicates that the mobile is in active mode. When all the borders of boxes are displayed in red it indicates that the mobile is in dedicated mode. Dx indicate the signaling channel SDCCH (where x is the number of this channel in the slot), TF indicate *full rate traffic* channel and APC is the *adaptive power control* (i.e. dynamic power control).
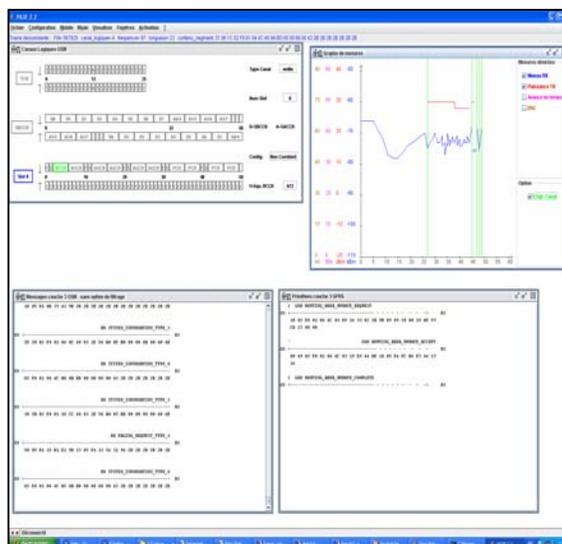

Figure 4: VIGIE main window containing several windows (including the Graph Measure window that contains DSC).

The *Graph Measurement* window shows the graphical plots of various parameters we decided

to group together including the plot of DSC counter we added recently. Four plots are possible when this window is selected, and there is an option to choose the desired plot using a check box on this window. In this window, we plot Rx level (dBm), Tx power (dBm), channel change and DSC (integer) against time, while we plot the timing advance on the x axis.

5. DEVELOPING THE GPRS LOGICAL SCREEN

5.1 Integrating the DSC into the Graph Measurement Screen

The downlink signaling failure is based on the downlink signaling counter (DSC). When an MS camps on a cell, the DSC shall be initialized to a value equal to the nearest integer to 90/N; where N is the BS_PA_MFRMS parameter for that cell (see reference 1). The MS is required to attempt to decode a paging message every time its paging sub channel is active; therefore the network activates the paging sub channel for a given MS every BS_PA_MFRMS multiframes. In case *discontinuous reception* (DRX) split is supported, the mobile listens to its paging sub channel every $1/N_{DRX}$ multiframes [1]. Thereafter, whenever the MS attempts to decode a message in its paging sub channel; if a message is successfully decoded i.e. *bad frame indication* =0 (BFI=0), the DSC is incremented by 1, but never beyond a maximum value (parameter of the radio configuration of the cell) , otherwise DSC is decreased by 4. When DSC$\leq$ 0, a downlink signaling failure shall be declared and this ultimately results in cell reselection [1].

For GPRS, an MS in packet idle mode follows the same procedure. The counter DSC is initialized each time the MS leaves packet transfer mode. In case of DRX period split is supported, DSC shall be initialized to a value equal to the nearest integer to max (10, $90*N_{DRX}$), where NDRX is the average number of monitored blocks per multiframe according to its paging group.

The DSC support has been developed for the trace mobile SAGEM 0T190 and OT290. To retrieve the DSC information from these mobiles, we have developed several functions that ask the mobile to send this information to VIGIE. We have also developed a driver that retrieves the DSC values contained in the proprietary frame format [2] and then translate them into a generic report that is used by the graph measurement screen.

5.2 Specification of the GPRS Window

This specification describes how the window we developed behaves and reacts to the decoding of each type of   RLC/MAC PDU (*packet data unit*). This window is made up of labels, text fields as well as graphics. The encoding of RLC/MAC blocks was defined by the means of *concrete syntax notation no 1* (CSN.1). The CSN.1 is a descriptive language for digital message encoding, which enables the description of the structure of message down to the bit level, and is particularly useful to describe bit-efficient encoding [4]. The RLC/MAC specification uses CSN.1 to define the whole of valid blocks which can be exchanged between the MS and the BTS on the logical channels specific to the GPRS [3].

The Temporary block flow (TBF) concept: the TBF is a logical connection between the RR entity at the MS side and the RR entity at the network side to support the unidirectional transfer of *logical link control* (LLC) protocol data units over *packet data channel* (PDCH) [11]. The TBF exists as much as the transmitter has in memory the data to transmit, which can correspond to the broadcast of several LLC packets [11]. There are two types of TBF, the *downlink TBF* is one in which data flow goes from the network to the mobile. The mobile returns acknowledgements and measurement to the network. Here the network sends message of pre-allocation to the MS specifying which blocks to decode in the slots allocated to it; some of these blocks may not be intended for this MS, but can carry data for another MS. The final recipient of the block is designated by the *temporary flow identifier* (TFI) field included in the block and usually the MS will find in one of these blocks an allocation for the uplink that will specify which block to transmit its acknowledgement and measurements.

In the *uplink TBF,* principal data flow goes from the MS to the network and it is the network that manages the allocation of the resources on the uplink (it manages the scheduling between mobiles). The mobile thus listens to "orders" from the network on the downlink to know which of the slots it can transmit on. These "orders" are identified by the TFI, it must also listen on the downlink for the acknowledgement of the packets it transmits. There are two possible allocations on the uplink – dynamic allocation and static allocation.

In dynamic allocation, MS receives an identifier called *uplink state flag* (USF) by slot which it manages and then listens on the downlink. When it locates its identifier in the downlink block, it knows it can transmit starting from the following block.   In static allocation, MS receives a message indicating the blocks in which it will be able to transmit for certain period. This allocation is limited to 128 blocks but can be repeated for another period; the mobile only knows if the allocation is renewed during acknowledgement. Thus TBF implies transmission in two directions,

which could be uplink or downlink. It is possible for a mobile to have two TFIs, a TFI uplink and a TFI downlink, which shows that these two aspects are independent, hence there, could be four states: TBF not in progress, UPLINK TBF is in progress, DOWNLINK TBF is in progress and UPLINK TBF and DOWNLINK TBF are in progress.

We propose a graphic interface (see figure 6), which shows how the resource allocation functions on the GPRS radio interface. This logical *screen* comprises of up to 10 representations of the 52 multiframes structures. The first group of four represents the downlink, a representation for each slot on which the mobile may be listening. The next group of four 52 multiframes are those of the uplink. The last two 52 multiframes represent the slot containing the *packet BCCH* (PBCCH) if used[1] and the slot containing the *packet common control channel* (PCCCH[2]). The other label fields shows how we display other important parameters, like the TFI downlink and uplink, the USF of the mobile, and the coding scheme (CS) for the uplink and the downlink.
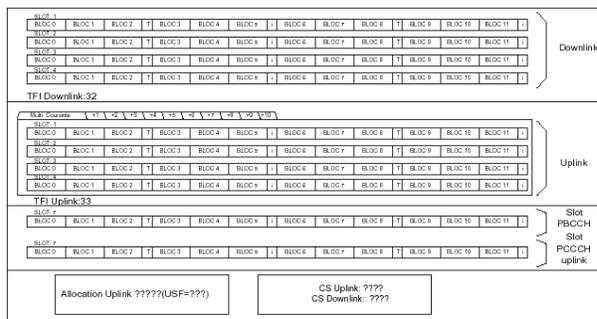

Figure 5: The proposed radio interface for GPRS logical   screen

5.3 Decoding of the Blocks

The specification of how the proposed interfaces must react to the reception of RLC/MAC blocks is based on their definition in CSN.1. As we have described above, we wrote the program from the syntax of CSN.1 to create a procedure which is able to determine if the bit strings subjected to it (procedure) belongs to the set of bit strings defined by the syntax and which, if necessary, can isolate each sub string named in this syntax. We thus specify the reactions of our program according to the values of these sub strings; and if these sub strings would not be present, the program should not have any reaction relative to its value except if explicitly indicated.

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[1] If the PBCCH is used, only 3 representation of the DOWNLINK multiframe can be used, since PBCCH occupies a DOWNLINK slot, this slot in addition to PBCCH can also transport data for the mobile.

[2] Same remark as for the PBCCH slot, but for the UPLINK multiframe.

CONCLUSION

GSM has evolved over the years, upon which advanced systems such as GPRS, EDGE and UMTS are based. To understand these advanced systems, however, a good understanding of the GSM system is necessary. We have proposed and developed simplified GUIs that will allow the users monitor and understand the sequences of a various tasks between the MS and the network over the air interface. We finally demonstrated the modularity in our software architecture by adding another window - the GPRS radio resources allocation window.

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