Remote Testing for Residential Gateways

Luca De Vito[1,2] Paolo Fiore[2] Sergio Rapuano[2]

[1] *Telsey Telecommunications, Benevento Lab, Via dei Sanniti, 1, 82018, S. Giorgio del Sannio (BN), ITALY. Phone/Fax: +39 0824 51449, http://www.telsey.com*
[2] *Università degli Studi del Sannio – Faculty of Engineering – P.za Roma – 82100 Benevento – ITALY Phone +39.0824.305804 - Fax +39.0824.305840 - E-mail: {devito, fiore, rapuano}@unisannio.it http://lesim1.ing.unisannio.it*

Abstract – A residential gateway is a network device employed in the Small Office / Home Office (SOHO) field. It is the front-end allowing the SOHO customers to connect their own network to the Service Provider's (SP) one. The paper deals with the problem of ensuring residential gateway interoperability with different SOHO and SP networks also when the manufacturer's and SP's test benches are different. In particular, a remote testing system is proposed enabling the manufacturer to test its device inside the SP network. The proposed solution consists of a remote testing board to be connected to the gateway under test within the SP laboratory and managed by the manufacturer. The solution has been implemented and validated for the Gateway ADapter / Gateway ADapter Mixed (GAD/GADM) gateways produced by Telsey Telecommunications.

I. Introduction

The coverage of broadband digital communications is continuously increasing [1], giving to the Internet SPs the possibility of offering additional services to the customers. Some of them currently offer phone calls exploiting the Voice over IP (VoIP) technology, and TV on demand, using the same physical connection [2].

To meet the requirements of connecting the different devices of the SOHO network (phone, data, etc.) among each other and with the SP one, an interfacing device is needed. The connection is guaranteed by a router, called *residential gateway* (RG) [3]-[5]. There are many kinds of such devices, but the most part of them have common characteristics, like broadband access to Digital Subscriber Line (DSL), protection from external intrusions, Ethernet connections to the customer's LAN. Of course, each RG has to meet the requirements of users and SPs. The users want to gain access to the latest services such as broadband Internet, security and assistance services, audio and/or video on demand or home monitoring and control in the easiest way [6]. On the other side the SPs should rely on RGs to design and provide new services to the customers regardless of the SOHO network type.

The RG enables such advanced services by routing different data sources into an IP packet stream over Internet. It is connected to the SP network and to the customer devices, such as phones and TV or LAN, by means of different physical interfaces (optical, copper or wireless networks), and different communication protocols. The RG should fit into very different operating environments without requiring additional efforts form the SP. However, testing these gateways for interoperability with different network devices is still an open problem for the manufacturers.

In order to assure the required level of versatility, the manufacturer has to carry out an extensive suite of tests in a test bench reproducing the target networks the RG could be connected to [7]. This will require i.e. a DSL simulator and a DSL Access Multiplexer (DSLAM) for gateways connecting to DSL communication networks, a H323 protocol gatekeeper, required for VoIP services, a File Transfer Protocol (FTP) server, a web and a Domain Name System (DNS) server, a phone traffic simulator, an Ethernet traffic simulator. Those tests should be carried out following the specifications of the SP that should point out the type of its network devices and the profile of the customer network.

Usually each provider will rely on a huge network, with several servers and active devices such as routers, gateways, switches, typically from different manufacturers. Those devices, due to differences in the management software, are not fully compatible among each other and with the RG, although they nominally comply the standards. Moreover, as each manufacturer usually produces different kinds of RG for different SPs, its test bench does not reproduce exactly the operating environment of each RG type. For these reasons it is quite impossible to assure that no interoperability problem will arise during the SP compliance tests or even on the field.

In some cases, RGs that have been successfully tested in the manufacturer's laboratories don't work correctly on the field or don't pass the tests in the SP laboratory and have to be sent back to the manu-

facturer (Fig.1). The most frequent cause of this lack of interoperability is the software configuration of the device. Therefore a return to factory is not actually necessary. Moreover, due to the differences in the test benches it is possible that the RG passes again the manufacturer tests. In such cases the manufacturer has to send skilled technicians to the SP laboratory, to carry out the tests in the SP network.
The paper proposes a new approach that allows the manufacturer to gain remote access to the RG functionalities by means of a Remote Testing Board (RTB). By means of the RTB it is possible to carry out the necessary tests while the RG is in its actual operating conditions without sending people to the SP lab.
This approach has been validated focusing, as a case study, on the GAD/GADM gateway family produced by Telsey Telecommunications. The prototype of a RTB, to be delivered to the SP with the gateway, has been designed and realized for the Telsey Telecommunications devices. The RTB provides the manufacturer with a full access to the gateway by means of a simple Telnet session. The hardware architecture and the developed firmware are described in the paper. The following Section II summarizes the gateway testing needs, Section III introduces the specific case study, Section IV presents the hardware and software architectures of the proposed solution. Finally, Section V reports the results of the first validation.

II. Testing of residential gateways

A typical RG has got different functionalities, and different interfaces to the external world. It can have PSTN (Public Switched Telephone Network) ports for analogue phones, Ethernet ports to connect to a computer network, an uplink to the SP (it can be xDSL, Ethernet, optical, etc., depending on the provider network), an RS-232 interface for the local management. The ideal test bench should be capable of verifying the functions of all the produced RGs. In particular, testing an xDSL RG requires an xDSL line simulator and a DSLAM; testing an optical RG requires an optoelectronic media converter, and so on. Some IP network devices, like gatekeepers, network servers (DHCP, FTP, Telnet, DNS and so on), traffic generators, are also required. Obviously it’s not possible to reproduce in a laboratory all the possible scenarios in which the RG will work, i.e. bigger offices working with fibre optic backbones, smaller ones or homes with DSL or ISDN (Integrated Services Digital Network) lines. Each SP uses a number of network devices, provided by different producers. As the network infrastructures are very different from each other, and it’s probable that some incompatibilities arise when the RG is connected to devices not present in the manufacturer’s laboratory. Therefore, often the testing carried out in the manufacturer’s laboratories cannot guarantee the effective interoperability of the RG with the SP’s network. For such a reason, the manufacturer should provide the SP with a field support during the installation or the in-service testing phases.
During those phases, skilled personnel from the manufacturer’s company have to repeat the tests in the provider’s laboratory, in order to assert the RG interoperability and solve the possible software problems. Currently, the only alternative to this expensive support consists in accessing the RG from a remote site using the Internet. Most of the RGs already include a web server and a Telnet server for such a purpose. However, for security reasons only a few operations are allowed from the Internet; mostly

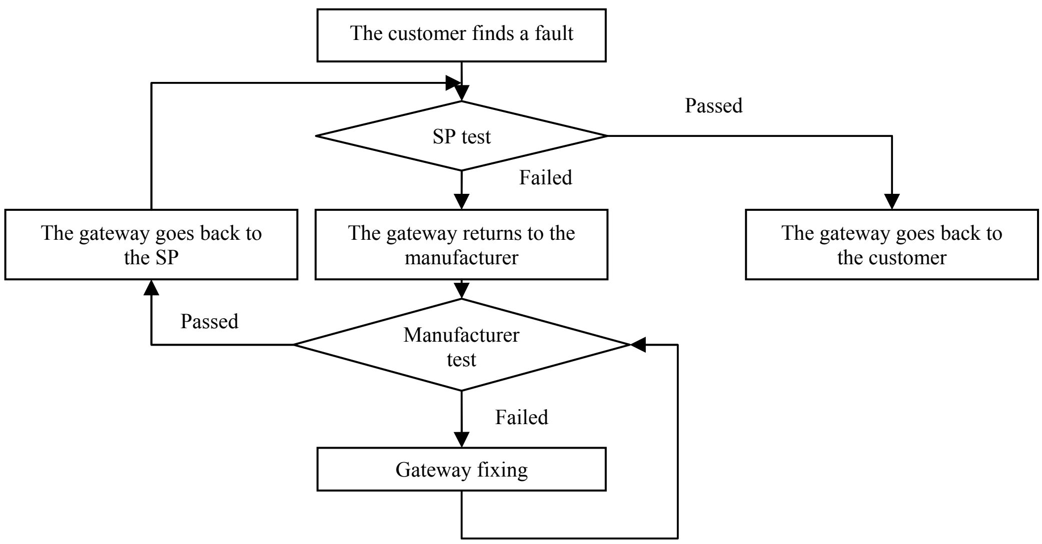

Figure 1. Maintenance flow chart.

they are just a few configuration options. The only way to access all the logs, registers, and debug messages or to introduce low-level changes in the software or firmware on the field is the RS-232 serial interface, which is not accessible from the Internet.

III. Telsey Telecommunications residential gateways

Telsey Telecommunications produces several models of RGs, they are different from the WAN (Wide Area Network) and the LAN side connections. All of them integrate some PSTN plugs, an optical, ISDN, DSL or Ethernet uplink to the provider network depending on the model, 4 Ethernet downlinks, and an RS-232 serial interface for local monitoring and management.
The main backbone of the Telsey Telecommunications test bench is based on Ethernet standard, therefore the RGs that don't have an Ethernet uplink require an Ethernet adapter. Optical RGs require for example a Media Converter, and DSL RGs require a DSLAM.
The Telsey Telecommunications test bench includes a Gatekeeper, a WWW, an FTP, a TFTP (Trivial File Transfer Protocol), a DNS and a DHCP server, a Spirent Abacus VoIP traffic simulator, a Spirent Smartbits Ethernet data traffic simulator.
As above reported, such a complex test bench still evidences interoperability problems discovered only when the RG is working inside the SP network. Therefore, Telsey uses to send skilled technicians to the SP labs, to test again the device functionality and make changes on the field.

IV. The proposed solution

In order to overcome the above quoted limitations on RG testing, the paper proposes a RTB, designed and realized to carry out the tests in the SP's lab. The board should be connected to all the ports of the RG, and carry out a suite of tests under the remote control of the manufacturer's skilled personnel as shown in Fig.2. As it can be seen form the conceptual block scheme in the figure, the board is connected directly to the RG ports, and should execute the following operations while the RG is working in real conditions in the SP laboratory: (i) PSTN port test; (ii) throughput test; (iii) RG management.
For security reasons the RTB is connected to the manufacturer's laboratory via a Virtual Private Network (VPN) over Internet. In order to test the RG switching functions, when available, an Ethernet interface is required. In order to test the PSTN ports it is necessary to generate voice traffic, the easiest solution to this aim is to use modems, that could be integrated in the RTB as hardware modules. Otherwise, external devices can be adopted by controlling them from serial interfaces. In the second case, even if the SP has not modems in its laboratory they are small and light enough to be delivered with the RTB. It will be necessary a number of serial ports and external modems equal to the number of PSTN ports increased by one. The additional port/modem couple will be used to test the voice connectivity to the SP phone line. An additional serial interface should be integrated in the RTB for management purposes. As above stated, through this interface it is possible to manage all the operating parameters and internal registers of the device under test. It is also possible to check the logs and debug messages as well as to download software updates. The testing board also requires a WAN interface, for remote controlling of the operations.

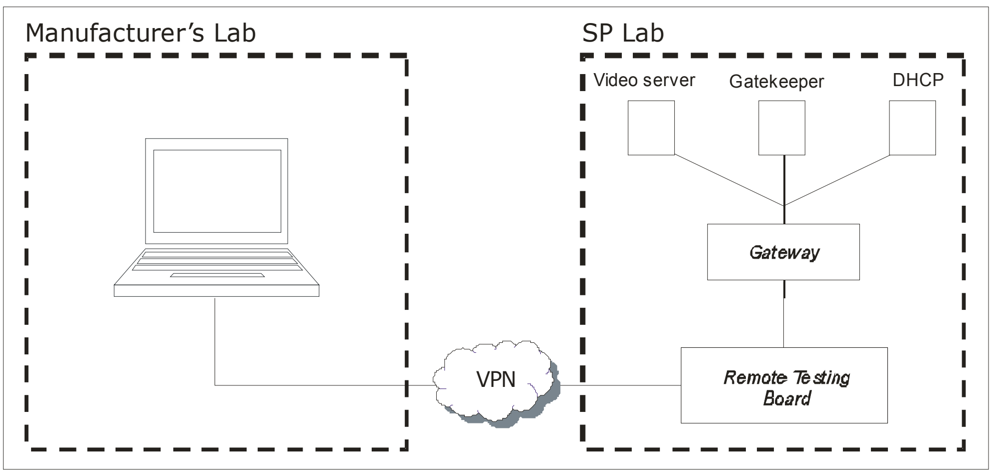

Figure 2. Remote control of test execution: conceptual block scheme.

A WAN interface as a DSL one could be integrated, but, as the Internet will probably be accessed through an external firewall and the SP LAN, an Ethernet uplink has been implemented first.
In order to validate such solution, an RTB prototype has been realized for the Telsey GAD/GADM and equivalent RGs. Such device has been chosen as it integrates a subset of all possible connection ports, except the optical and DSL ones, so that the developed prototype testing board could be easily extended by adding new interface modules.

A. Hardware architecture

For a rapid RTB prototyping, an Altera Nios Development Kit based on Cyclone processor has been chosen [8].
The Cyclone field programmable gate array family is based on a 1.5-V, 0.13-µm process, with densities up to 20060 logic elements (LEs) and up to 288 kbits of RAM and features like phase locked loops (PLLs) for clocking and a dedicated double data rate (DDR) interface to meet DDR SDRAM and fast cycle RAM (FCRAM) memory requirements.
The development board has two RS-232 serial ports and an Ethernet port with RJ-45 connector. To check the RG functionality it is necessary to test any combination of phone calls directed to and coming from the two PSTN ports of the chosen RG, and the external telephone line. This can be done using three analog modems connected to the RTB through RS-232 serial ports. Two of those modems are to be connected between each PSTN port and one RS-232 of the RTB, for carrying out the PSTN tests. The third modem is used to connect the RTB to the external telephone line. A fourth RS-232 port is necessary in order to connect the RTB with the console port of the RG. Therefore, two additional RS-232 interfaces have been realized and connected to the development board. Moreover in order to test the RG Ethernet switch and the WAN connection, an MII interface has been realized.
The gate array included in the Cyclone processor has been programmed by using Quartus II development environment from Altera adding the RS-232 interface cores from Altera, and a customized core developed for the MII interface. The existing RJ-45 connector has been used for accessing the Internet through the SP LAN.
The resulting prototype hardware scheme is reported in Fig.3, as well as the accessory hardware needed for the tests.

B. Software architecture

Two testing routines have been developed and executed on the Cyclone processor for testing analog and digital interfaces of the RG. The first routine tests automatically the PSTN ports by simulating any combination of phone calls directed to and coming from the telephone line through the RG. The routine controls the modems connected to the three dedicated RS-232 ports and records the messages coming from the modems, to check if the PSTN ports are working correctly. The second routine implements a traffic generator giving the possibility to customize the Ethernet in this way it is possible to test both

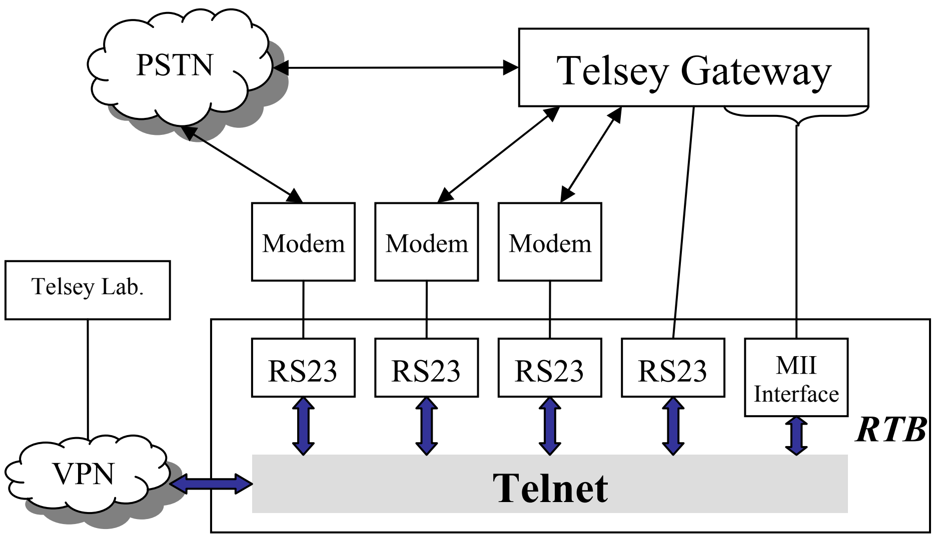

Figure 3. RTB and gateway connections.

the LAN and the WAN side of the RG, it is only needed to change the packet destination address.
The routines can be launched remotely by means of a Telnet server that has been implemented on the Cyclone processor. Moreover, the manufacturer's technicians have full access to the RG console port through a Telnet connection, and hence they can see the diagnostic messages produced by the RG as they have physical access to the device. As soon as the Telnet session to the RTB is started, a menu is shown, and from there it's possible to start the tests: call test, throughput test, connection to RG.
This result has been achieved by implementing an Ethernet to serial bridge on the RTB.
By means of this solution it could be even possible to remotely update the RG software in a safe way.

V. Experimental validation

An example of the SP laboratory and how the RTB will work in its actual operating conditions is shown in Fig. 4.
In the figure a subset of a real SP laboratory devices is shown, describing the Telsey Telecommunications test bench. It includes DSLAM, a BPX (Multiservice Switch), some STM-1 connections (fibre optic), a data and voice Broadband Remote Access Server (Cisco 7206) for registration and authentication, an H323 gatekeeper (Cisco 2600), a VoIP gateway (5300/5350), and a PSTN network. The Telsey RG is located in the IP network, and the RTB acts as an interface between the RG and the manufacturer laboratory, through a VPN, allowing the manufacturer technicians to test the RG under real work conditions, without moving from their laboratory. In order to validate the developed RTB prototype, the board has been carried out in the *Telsey Benevento lab*. A faulty RG with a hardware design error causing a huge packet loss has been first analyzed by managing it via a local PC connected to the console port. Then the RTB has been connected to the RG and the same tests have been carried out in the set up described in Fig.4 substituting the VPN with an Ethernet LAN and using a PC as remote control unit on the manufacturer's side. The traffic generator has been remotely started to sent probe packets from the RTB to the RG and the same packet loss as in the previous phase has been detected from the remote control unit.
Then, the same procedure has been adopted for validating the PSTN testing capabilities of the RTB. A malfunctioning on the phone line has been simulated, by physically disconnecting the connector. In such case the calling modem gets no answer from the called one, and the system is able to correctly recognise if the line is busy or if the connection is missing. The resulting Telnet report is shown in Fig.5. A similar test has been carried out keeping the line busy with similar results.
By means of serial port RG management also it has been possible to verify the correct operations of VoIP traffic subsystem. It has also been possible to remotely control the signalling phases involved in the call between two endpoints.

VI. Conclusions

The paper proposes a solution to interoperability testing of RGs by means of remote testing board designed to stress, manage and control the device under test as it was in the manufacturer's laboratory also if it is in the SP one.

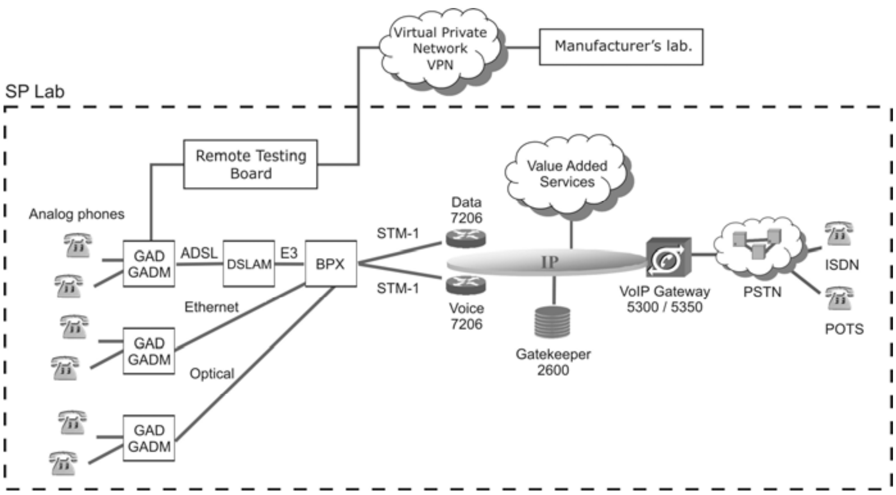

Fig. 4. Remote testing of residential gateways.

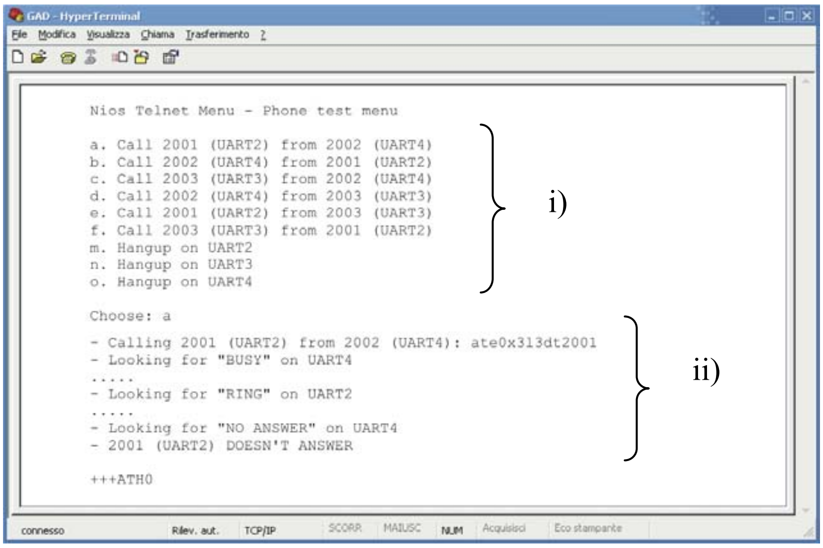

Fig. 5. Test menu (i) and results (ii) with a disconnected phone line. The test *a* fails when calling PSTN port 2 from port 4.

This solution overcomes the current necessity of sending back the RG to the manufacturer's lab in order to investigate on the troubles found thus ensuring time and resource saving, The phase of return and testing in manufacturer's lab are eliminated (or, at least, postponed, just in case the RG has an hardware fault), and it's possible to test the RG on field.
There are also some other interesting evolutions of the system.
With further development, it could be possible to realize a prototype starting from the development kit, in order to have a smaller and lighter device, that can be easily sent to the SP lab and connected to the network; it's also possible to combine the network switch with the FPGA.
It can also be realized a RG with an integrated RTB. This device can be monitored and maintained even in the customer site.
Of course it's also possible to develop similar RTBs for other gateway models.

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