Communicating Agents in the Reconfigurability Context

Karim El-Khazen, Guillaume Vivier, Nicolas Lhuillier
Motorola Labs (CRM) – European Communications Research Lab
Parc des Algorithmes Saint-Aubin, 91193 Gif-sur-Yvette, France
{elkhazen,vivier,lhuillier}@crm.mot.com

Motivation

The **management of reconfigurable terminals** is becoming a topic of great interest in the wireless industry. Recent trends on wireless technologies as well as on software progress make the reconfiguration of wireless equipments not only an interesting feature but also an achievable one:

- **Novel application and air interface.** Future applications, protocols, waveforms, cannot be anticipated now. Therefore, it is quite impossible to provision at the design time all the features that will be needed in the device terminal. Hence reconfigurable equipments will become able to download and run new functionality.
- **New band allocated for mobile wireless services.** A terminal can fully benefit from the new bands as long as it becomes agile.
- **From military to public application of Software Definable Radio (SDR).** While SDR was primarily devoted to military applications, it is nowadays moving to the public area, especially in the Beyond 3G trend.
- **Beyond 3G trend (B3G).** The evolution of telecommunication systems is going towards the convergence of different radio access technology around an IP-based core network. To benefit from these heterogeneous radio systems, devices should be able to communicate through all of the radio access systems and to run all of the possible protocol stacks, applications etc.

This latter vision deserves to be further developed. Actually, telecommunications standard traditionally followed a 10-year regular life cycle. Now, the standards, whether they come from the telecommunications industry such as cellular phone systems or from the computer industry as the WLAN IEEE 802.11x standards, or from the broadcast one, converge towards the delivery of IP content. The B3G trend consists in an open, smooth and flexible integration of these different radio access technology standards to make them complementing instead of competing.

This trend assumes that future terminal will be **multi-technology enabled**. Such ability could be provided efficiently by the reconfiguration of the terminal radio access layer parts, also known as Reconfigurable Radio, inherited from the SDR framework.

To handle the growing need of flexibility brought by the B3G vision and by the Reconfigurable Radio terminals, specific attention should be given to **equipment management**, a growing activity as it can be witnessed in several bodies such as 3GPP, Telecom Management Forum, SyncML initiative, SDR Forum, WWRF...

This paper investigates an approach for managing equipments based on the use of distributed software. A simple architecture is presented allowing the reconfiguration and the management of reconfigurable equipment. It is based on the use of **communicating agents**, which provides a way for negotiating the appropriate configuration between the network and the terminal as well as easy context discovery or autonomous decision handling.

Equipment Management

Managing agile terminals is indeed a greater challenge than managing monolithic systems developed by a single vendor and communicating over proprietary interfaces and protocols. Management and reconfiguration of multi-technology (RATs) and multi-vendor systems, where software components are open and upgradeable, are of great interest to network operators and third-party service providers.

These service and network providers are looking at terminal management in order, for example, to improve their customer support, improve their network performance, and offer enhanced value-added services. The increase of device capabilities and the new expending services are raising the support costs in an exponential way. The advent of terminal management over the air will help the service and network providers.

With this perspective, complete management architecture is needed for such reconfiguration of terminals and network equipments.

Communicating Agents

Software agent technology encountered a renewal over the last decade, due to its foreseen suitability to the Internet ecosystem (e.g. search engines). However, the agent paradigm in itself is rather old and is sometimes dated from 1960. Because of its age, various approaches and uses of software agents have been made, so that it is now quite difficult to give a consensually agreed definition of an agent. However **all agents share some common properties, which are of interest to management of reconfigurable equipments**:

- **Autonomy:** agents are supposed to act and behave without the direct intervention of humans. Therefore, they must perform some control over their own actions and internal state;
- **Sociability:** agents form a community, which communicate and interact through semantically rich messages expressed in a structured language;
- **Pro-activity:** agents do not simply react in response to their environment; they are able to take initiatives when they consider to be appropriate;
- **Adaptability:** agents are able to learn on their experiences and improve their behavior accordingly.

Some elements suggest the evaluation of agent technology for terminal reconfiguration: Agent technology has today gained in maturity, as some commercial products include proprietary agents. Additionally, agents have recently moved from the Internet to the wireless device and can be executed on constrained mobile phones [1].

In this perspective, an overall management architecture was proposed, as described in next paragraph.

Possible System Architecture

The figure 1 depicts the overall system architecture, including a reconfigurable device. This device is built around various components. The terminal includes a reconfigurable modem that allows changing some radio parameters such as forward error correction coding rate, data rate, or even waveform type. Software radio modems [2] are typical examples of reconfigurable modems where the new configuration simply consists of changing the execution code. Such modems are appearing, see for instance [3][4] or [5] but obviously, all the existing radio transceivers are not available today in full software version.

An agent platform runs on top of the operating system. This platform provides the intelligence and the communication capability for triggering the appropriate configuration actions. It includes the following capabilities:

- Monitoring and discovery of the environment, in order to gather the information related to the available radio access technologies, the capability of the device, in terms of memory, processing power,
- Selection and negotiation of reconfiguration actions. Actually, based on its own context analysis, the device may want to change its own radio parameters but the radio operator, which has a larger view of the system and other priorities, may invalidate this choice.

This latter capability yields to the need of having a **distributed intelligence** for managing the reconfiguration. Basically, the reconfiguration involves the equipment as well as supporting

functions in the network. The figure 1 shows a repository where all the known radio parameters and waveforms are stored, controlled by an other agent belonging to the network. This agent provides the basic security functions (download authorizations, subscription restriction information…). On the other hand, this agent could also prevent the user from downloading uncertified waveforms or even virus.

The monitoring operations described earlier could be performed in two ways, either retrieving the information directly or through the use of dedicated agents. For instance, an agent could be responsible for providing the most updated information on the terminal capabilities, and another one for providing the current environment characteristics in terms of networks availability…

The proposed management architecture could be used over any access technology, such as GSM/GPRS, WLAN and even Bluetooth or Ethernet…

We implemented the architecture depicted in Figure 1 on classical Linux-based laptops running JADE-LEAP agent platform [6][7] and demonstrated basic configuration action such as parameterizations of a WLAN networks, as described in Figure 2.

The intelligence in the terminal consists only in monitoring, filtering and managing the terminal capabilities (memory, power, cards…), the context (available networks…) and the available services (voice, video-conference…). Moreover, the user preferences rules are limited to a preference list, taking into account the requested services and the prices of the access. The repository in the network contains the WLAN connectivity information.

Expected Results

Even if reconfigurability has been for a long time a topic of interest with outcomes mostly limited to military applications, the convergence between heterogeneous radio systems provides a field of great application to configuration management of flexible equipments.

Though it does not include a real negotiation between the agents, these experiments demonstrate how the management architecture could be used, for instance, for getting access to the WLAN network. In the studied scenario, only parameters were retrieved from the repository in the network. However, pieces of code could be exchanged between the terminal and the network repository and executed locally. For instance, the terminal could retrieve the necessary drivers for a new network card, updated waveform software code and install them on the terminal. Experiments based on this prototype shows that using distributed softwares is a good candidate for managing fully reconfigurable systems.

In fact, agent technology is the subject of a lot of attention in the last years, and is often considered as the next step after the client/server and object-oriented programming paradigms.

Future work might consist in addressing more complex scenarios of use, and developing the intelligence aspects as well as modeling the information exchanged between the agents. Pros and cons of similar distributed approaches or more centralized ones should be evaluated too, in order to fairly take into account the most recent progresses in the wireless industry.

List of References

[1] G. Caire, N. Lhuillier, G. Rimassa, “A communication protocol for agents on handheld devices”, AAMAS Conference, Workshop on Ubiquitous Agents on embedded, wearable and mobile devices, Bologna, July 2002

[2] Joseph Mitola III “Cognitive Radio: An Integrated Agent Architecture for Software Defined Radio”, Dissertation Thesis, Royal Institute of Technology (KTH), Sweden.

[3] J. Chapin, V. Bose, “The Vanu Software Radio System”, 2002 Software Defined Radio Technical Conference, San Diego, November 2002, http://www.vanu.com

[4] C. Bonnet, L. Gauthier, P.A. Humblet, R. Knopp, A. Menouni-Hayar, Y. Moret, A. Nordio, D. Nussbaum, M. Wetterwald, “An all-IP Software Radio Architecture under RTLinux”, Special Issue on Software Radio In “Annales des Telecommunications”, Volume 57 N°7-8, July-August 2002

[5] GNU Software Defined Radio, http://www.gnu.org/software/gnuradio

[6] JADE, http://sharon.cselt.it/projects/jade/
[7] LEAP, http://leap.crm-paris.com
[8] FIPA, http://www.fipa.org

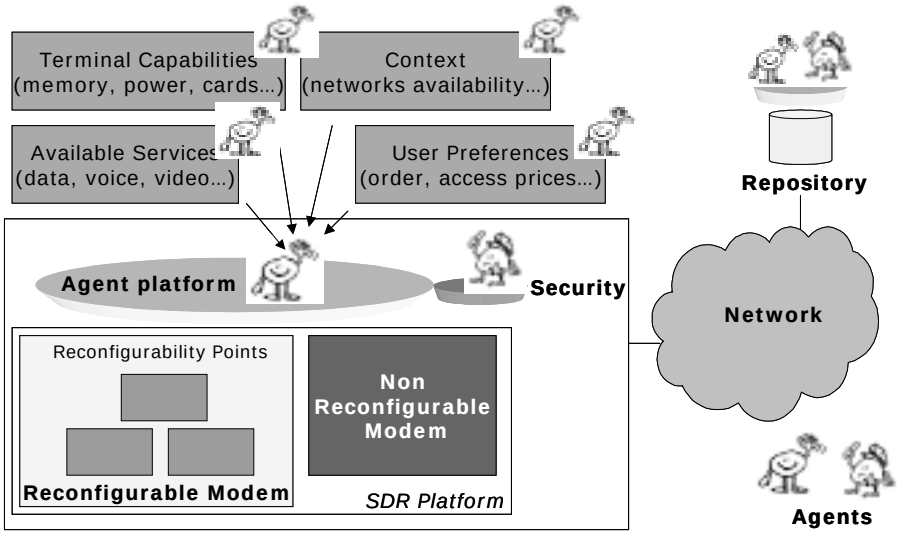

Figure 1: High level management architecture

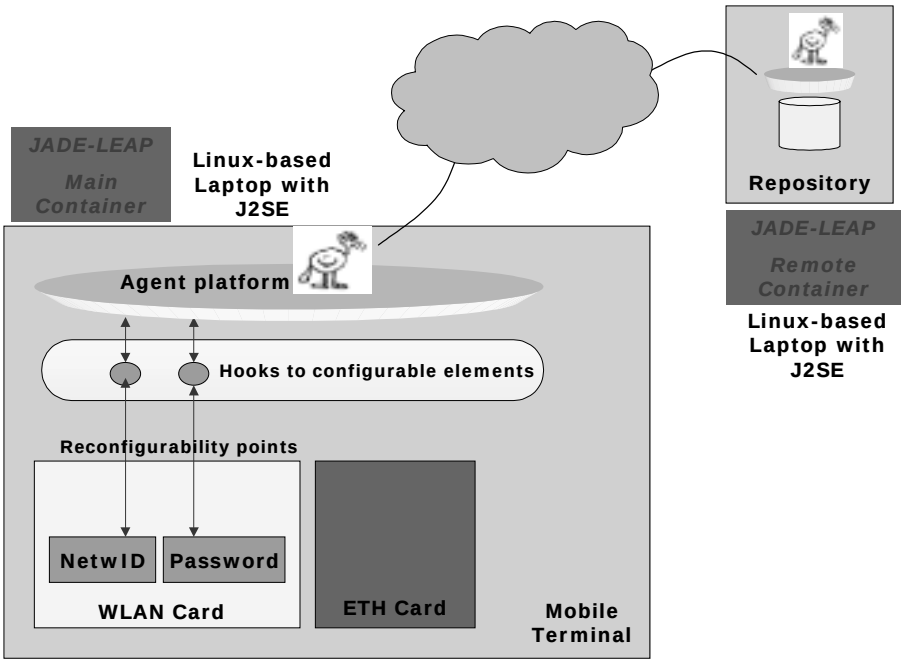

Figure 2: Demonstration Set-up