RFID tags for ambient intelligence: present solutions and future challenges

Hughes Metras

CEA/LETI
17 rue des Martyrs 38054 Grenoble, France
Hughes.metras@cea.fr

Abstract

The present paper aims at delivering a broad overview of current state of the art technologies in the field of RFID including standardization issues. On that basis the potential use of RFID in ambient intelligence (AmI) scenarios will be discussed highlighting the two main visions and paradigms that are proposed in the field: one concentrates all the information on centralized or distributed data servers that are accessed through web services pointed by the URL addresses stored in the tags read by the user; the other is built on the use of tags or sensors as a media to gather information in the close environment of the user in order to enrich its experience. Finally, we will have a look at the various tag functionalities and performances that need improvements to meet AmI requirements and we will discuss the associated research and technology development challenges.

1. Introduction

RFID techniques were born in the late 80s and early 90s and have benefited from a steady growth over the last fifteen years. After a diffusion in specific market niches where the economic interest could be proven (glass tags for animal identification, contactless ticketing for mass transportation systems, library or laundry management, the technology is now poised to disseminate in all production and distribution areas through the EPC initiative in the United States and its affiliate programs in Europe and Asia [1] [2]. *Figure 1* detailing the increasing number of patents filed in the filed over the last 10 years is a good illustration of this trend.

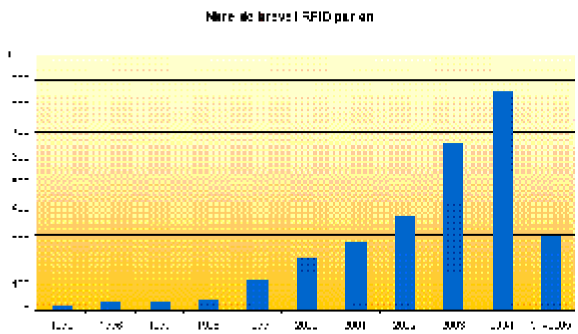

Figure 1: number of patents filed each year

However, many challenges are still facing RFID tags technology before it is widespread. The main one is presented as the cost of tags which should go down to 5 cents for the solution to compete really with existing bar code labels. Some of them are related to the physics of the system itself and other are linked to standardization and regulation issues around the world. RFID technology may make an appointment with Ambient Intelligence. This vision of the future elaborates on the basic assumption that any human being may be permanently surrounded by low cost distributed devices carrying context information. RFID tags are the main candidate solutions thanks to their low cost. In the future, the basic functionalities of current tags which are carrying a product ID may happen to be insufficient and additional capabilities maybe required by end users. When a tag is associated to a product or a location through a simple ID the main issue is the lack of context information transferred to the data base and as a result the lack of adequacy between the service returned to the user and the context. Future solutions will have to be capable of measuring and acquiring data from the users' behavior and the environment (T, P, humidity). The development of such functions will require tremendous efforts from both public laboratories and industrial development teams in areas such as material science, antenna design, electronics and micro electronics, packaging and assembly techniques.

2. Overview of RFID

An RFID system is made off two main components: a reader or interrogator and a tag or transponder. The reader sends an electromagnetic signal to the transponder. The signal provides to the tag energy and data. The tag answers back to the reader using the energy it received. *Figure 2* illustrates these basic functionalities and differentiates two situations: depending on the frequency of the carrier, the phenomena that govern the coupling effect between the interrogator and the transponder may be magnetic or electric. In the case of lower frequency (HF at 13.56 MHz) prevailing magnetic coupling leads to the requirements for coil antennas and short range communications.

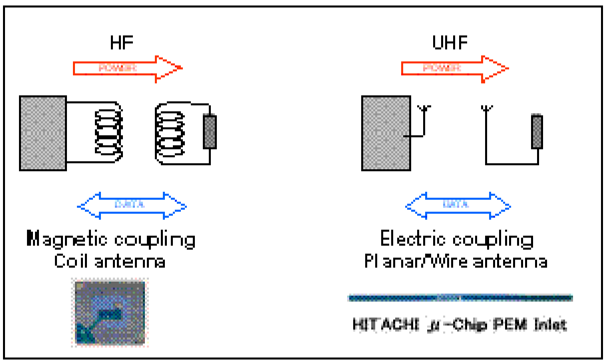

Figure 2: basic principles of RFID technology

At higher frequency (UHF 868 MHz, 915MHz or 2400 GHz) the coupling is electric, the antenna are dipoles or planar and the communication may reach longer range depending on the nature of the media between the reader and the tag.

2.1. Regulations & standardization issues

Some of the main drivers in the field of RFID are the standards and the constraints brought by local regulations. Two main issues are arising: the first one comes from the emitted power authorized from the reader. Whereas regulations for HF band (13.56 Mhz) are global, the situation in UHF is much more different. First of all the authorized power that a reader may emit is 8 times greater in the US (4W) than in Europe (500 mW). Moreover the frequency band vary from one area to the other preventing the easy spread of such frequency usage at a global scale and leading to higher cost solutions (multi frequency reader for instance).

The standards that are relevant for a good understanding of the situation are summarized in *Figure 3*. Contactless techniques are developed for two main applications: one aims at RFID solution for tracing of goods and people the other focuses on smart cards. As a result two families of standards pointed out.

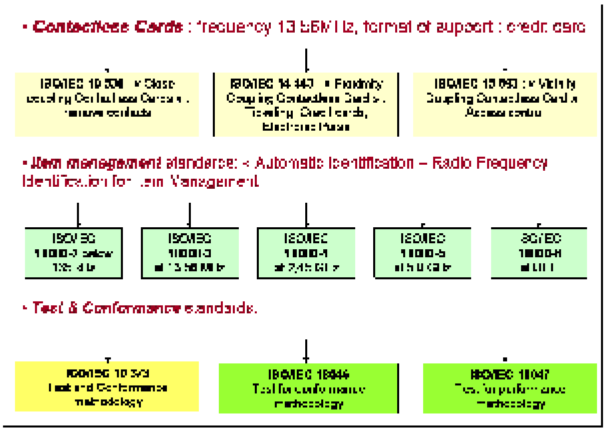

Figure 3: contactless communication standards.

The ISO 18000 family takes care of automatic identification issues addressing each of the major families of carrier frequencies whereas other standards families deal with credit card format solutions for ticketing, access control and banking applications. The last ones are addressing the test for conformance and performance issues to guaranty that various systems are evaluated through procedures that can be compared.

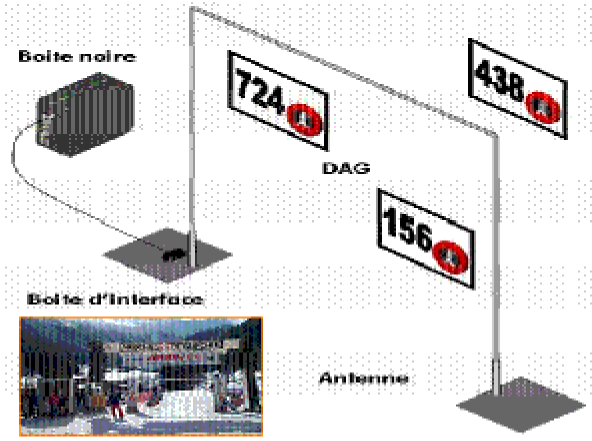

Figure 4: Dag-System for sport applications (source: dag-system).

2.2. Performance

Due to the previously presented EM characteristics HF systems are supposed to reach lower distances of communications than UHF systems. However, smart engineering solutions can allow to reach larger distances of communication this is the case of the 3D antenna developed by LETI 5 years ago during the project Delta or the large antenna systems developed by DAG-SYSTEMS [7] for sports applications (*figure 4*) where antennas up to 6 or 10 meters are used to identified and rank competitors during large sport events and competitions. The system work with disposable tags that are stuck to the participants' shirts and that are used for very different kind of applications: cross country, Nordic skiing, biking, motor bikes). The system is robust enough to work with tags presented with a strong inclination thanks to high quality factor transponders including some specific components added to the typical IC provided by semiconductor manufacturers.

As far as UHF systems are concerned VTT, Idesco, Rafsec and Atmel demonstrated in 2001 the first UHF system with a range of up to 4 meters for an emitted power of 500mW EIRP (European regulation). This was done as the result of a European Project called Palomar funded by the EC [11]. Today many reader manufacturers are claiming systems reaching range around 8 to 10 meters [8][10]. Systems in 2.4 GHz are more limited due to the strong attenuation of EM waves at the frequency in liquid or humid environments. UHF systems are much more directive that HF ones. UHF solutions around 900 MHz are strongly pushed by the EPC Global initiatives but end users such as Walmart itself recently acknowledged that HF systems maybe very relevant in some application scenarios.

2.3. Cost

The dissemination of RFID systems in logistic applications and large distribution systems depends on one main factor: the ability to reduce drastically the cost of each tag. The cost of an RFID tag does not come only from the cost of the silicon die but is a balanced mix of material (antenna) cost, silicon chip cost and assembly operations costs.

Figure 5 extracted from [3] illustrates the fact that RFID tags are aiming at becoming commodities in the 5 to 10 cents range. This means that both materials to be used and assembly solutions must be optimized.

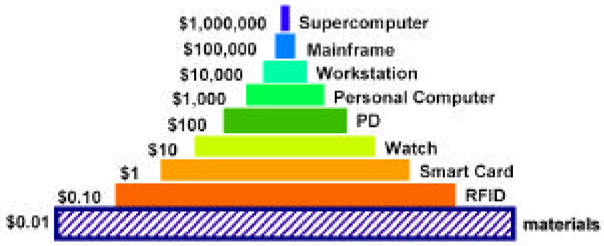

Figure 5: cost structure of various systems and devices

With the developments of tiny solutions such as Hitachi's µchip [9] whose surface is around 300µm * 300µm, the cost of the silicon area drops to very small values whereas dicing, assembling techniques are getting more complicated. Hitachi solved the problem by texturing flexible substrates where the silicon die can be placed through a shaking procedure. Dipole antennas for the 2.4 GHz chip are then printed on another substrate which is folded so that antennas and silicon dies can be collectively assembled in one step. The last innovation comes from the characteristics of the contact areas which are distributed on both side of the chip. The antenna which has been glued to one side may be then folded and connected to the other face of the die [12]. Alien Technology on the other end applies its micro fluidic assembly technology (originally designed for the manufacturing of micro-displays) to the low cost production of smart tags. Building on this technique Alien is becoming a major RFID tag and system provider. *Figure 6* extracted from [3] outlines the microfluidic assembly technique where chips are carried on to a substrate marked with tiny holes in which the silicon dies can fit perfectly.

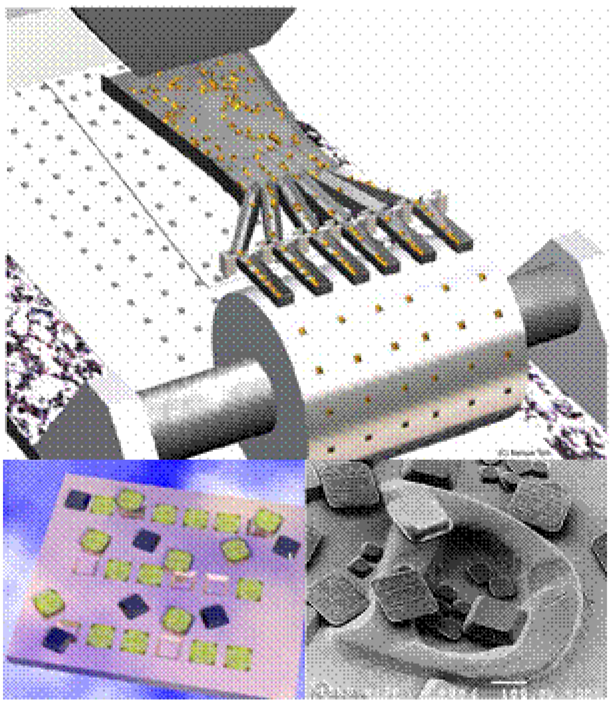

Figure 6: microfluidic assembly process (Alien Technology)

In the future manufacturers will try to benefit for on going research activities on printable electronics where low cost polymer or organic materials maybe deposited with printing techniques. Engineers will have to figure out how to make HF or even UHF communication front ends with transistor presenting very specific characteristics such as very low mobility of carriers.

3. Business models and links to AmI

3.1. Business models

When discussing with experts that have been operating in the area during the last ten to fifteen years it seems that two kinds of business models are envisioned for RFID. The first one, closer to EPC global philosophy aims at developing and disseminating ultra low cost tags with very limited features (EPC code of products stored in the tag memory) and to centralize the information on data servers managed by service operators. Here the value resides in the data management and *figure 7* is a good illustration of this business model where major actors from distributed computing networks and servers will play a central role.

IBM is by far the leader of patent holders in the field ahead of companies such as Intermec, Micron, Philips, TI or Japanese actors such as Hitachi, Matsushita; Mitsubishi or Toppan Printing. The strong involvement of companies such as Intel, SAP, Microsoft, Cisco in the recently launched RFID Centre in Bracknell (UK) is another illustration of this trend.

In Europe on the contrary, people are looking at ways to put more functions into the tags bringing local services and added value to the tag itself. This is illustrated by developments of temperature sensing tags for food chain monitoring (KSW Microtec – figure 8).
The French company DIPO uses active tags to propose key finder devices in rooms or homes.

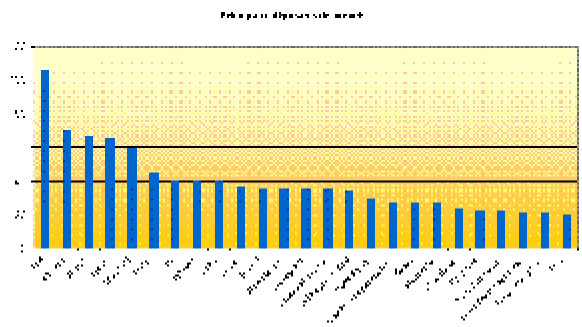

Figure 7: major world patent holders

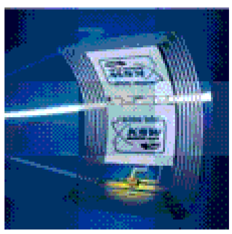

Figure 8: battery assisted tag for temperature sensing

3.2. Links to AmI

So far mainly industrial applications were discussed and detailed. The use of RFID for consumer application is pushed by the vision of finish actors such as VTT and Nokia where the mobile phone is seen as a major tool for accessing local information through various types of tags. The ongoing European project MIMOSA carries out this vision through the development of micro technology platforms for enhanced user interfaces and short range connectivity. Figure 9 sketches this vision very efficiently.

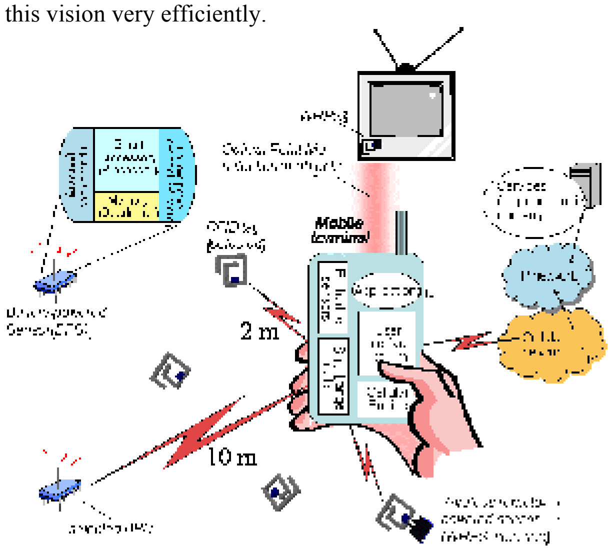

Figure 9: Mobile phone as gateway to AmI (MIMOSA project).

Recently discussed issues in the project revealed that AmI is based on the possibility to provide end users and consumers with en enriched set of information on their close environment and that this situation based services require more than the basic functionalities of tags pointing to a simple URL address where all the relevant information is supposed to be stored. Environmental data as well as personal behavior or monitoring parameters may be essential for providing relevant information or services to a given end user in proactive environment. User centric issues in this filed of proactive computing are studied in the French-Finish project ADAMOS. So far the use of ad hoc sensor networks based on fully active nodes has been explored as the natural solution for fulfilling those requirements [5]. We believe that the characteristics of RFID techniques coupled with sensing and energy storage blocks may bring an alternative to this vision by proposing an intermediate way between centralized approaches and active sensor nodes networks that need to provide energy storage, radio, sensor cells and interfaces as well as computing power and embedded software functions.

4. Future challenges

Various social and technical challenges will have to be tackled in the near future in order to position RFID as one of the major solution for accessing AmI services.

4.1. Privacy issues

One of the growing concerns in the field of RFID comes from consumer groups in the US that are worried by the possibilities offered by the technology to distributors to track user behaviors and profiles without offering him any possibility to keep control or to have full awareness of the situation. These strong reactions lead Benetton to step back in the implementation of rfid tags on clothes in 2003 and initiated some developments in the field. MIT and RSA proposed the notion of blocker tags in [13] and similar ideas should be explored and implemented by LETI in the European project DISCREET. The idea is to provide any user with a system that can either prevent unauthorized RFID interrogators readers from getting back exploitable information from its personal tags. One idea is to generate a signal that completely balance the return signal from the interrogated tag thus sending back no relevant information toi the reader.

4.2. Higher data rates

Another AmI functions that is envisioned for RFID tags is the possibility to download large amount of data from the tag using the rfid passive link. Applications range from low cost data loggers for environmental monitoring or medical care to multimedia applications where users could download music or video files from various media such as posters or magazines. In [6] it is explained how a 1.7 Mbits/s data rate could be reached for a HF contactless link targeting smart card applications. The use of multi level modulation for down and up links is discussed. Multilevel amplitude modulation is used for communication from the reader to the card (carrier frequency) and multi-phases modulation is used for the sub carrier frequency. The solution was implemented on 0,18 µm silicon CMOS technology. Today further solution at higher frequency should be explored.

4.3. Active or passive sensing tags

Another major challenge lies in the field of sensors. Many applications would be interested in multi sensing tags. Parameters to be acquired vary from shock to temperature and include pressure, humidity as well as more complex data (gas, physiological parameters). Two possibilities are under exploration: (i) passive sensors could be used to detect temperature, pressure or other parameters reaching thresholds.,(ii) other solutions are based on the coupling of very low power micro sensors to energy sources such as thin film rechargeable batteries. For some applications with legal implications time stamping functions will be required so that events happening to the product on which the tag is connected can be linked to a reliable date and time and thus associated to the operator in charge of the product at the time of the event. These tags will probably be restricted to high added value applications but similar problems arise for medical or home care applications where multi parameters have to be synchronized ands where the privacy or the security od the data may be critical.

5. Conclusions

Besides localization techniques, RFID tags as well as wireless sensors are probably the two major technologies that will allow to widely embed in the environment, devices that are able to bring contextual information to users and to service providers. RFID tags maybe of great use each time application specifications make it useless, difficult or impossible to use active radio ling between the sensor/tag and the user. This may come from poser requirements of sensors that may use all the power available in the batteries or when the sensor are only activated when the tags is accessed. Access to these data may require new low power memory technology as well as new air interfaces. Finally privacy issue will have to be addressed either through specific device development or through the development of a centralized security scheme.

Acknowledgements

I want to thanks the EC for supporting all the work performed in the European project MIMOSA and all the partners of this project for the enriching exchanges about technology developments, applications and new scenario exploration.

References

[1] www.epcglobalinc.org.
[2] www.ean-net.orgr
[3] Fletcher, R. (1997) *A Low-Cost Electromagnetic Tagging Technology for Wireless Identification, Sensing, and Tracking of Objects,* MIT Medialab
[4] Kaliski, B. (2004) *RFID privacy: Challenges & Progress*
[5] Chong, C.,Kumar, S. *Sensor networks: evolution, opportunities and challenges* Proceeding of the IEEE, Vol.91, NO 8, August 2003
[6] E. Crochon et al. , *New Emerging Technologies for Contactless Air Interfaces.* E-Smart 05
[7] www.dag-system.com
[8] www.allientechnology.com
[9] www.hitachi.co.jp
[10] www.tagproduct.com
[11] www.vtt.fi
[12] Kazuo Takaragi, Mitsuo Usami, Ryo Imura, Rei Itsuki, Tsuneo Satoh. "An Ultra Small Individual Recognition Security Chip," *IEEE Micro*, vol. 21, no. 6, pp. 43-49, November/December 2001.
[13] Juels, A. Rivest, R. Szydlo, M *The blocker tag: selective blocking of RFID tags for consumer privacy* (2003) Proceedings of the 10th ACM conference on Computer and communications security.