Integrated Wireless Systems: the Future has Arrived

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ABSTRACT

It is believed that we are just at the beginning with wireless, and that a new age is dawning for this breakthrough technology. Thanks to several years of industrial manufacturing in mass-market applications such as cellular phones, wireless technology has nowadays reached a level of maturity that, combined with other achievements arising from different fields, such as information technology, artificial intelligence, pervasive computing, science of new materials, and micro-electro-mechanical systems (MEMS), will enable the realization of a networked stream-flow of real-time information, that will accompany us in our daily life, in a total seamless, transparent fashion. As almost any application scenario will require the deployment of complex, miniaturized, almost "invisible" systems, operating with different wireless standards, hard technological challenges will have to be faced for designing and fabricating ultra-low-cost, re-configurable, and multi-mode heterogeneous smart micro-devices. But ongoing, unending progresses on wireless technology keeps the promise of helping to solve important societal problems in the health-care, safety, security, industry, environment sectors, and in general opening the possibility for an improved quality of life at work, on travel, at home, practically "everywhere, anytime".

Keywords: Wireless platforms, Microelectronics, Micro-Systems, Systems-On-Chip

1. INTRODUCTION

What is the future of wireless? In a recent interview involving visionary people from the science and engineering world [1], it came out that wireless is considered as one of the most prominent technologies for the coming decades, at the same level as other well-acknowledged ones, such as information technology, internet, the computer, artificial intelligence, quantum technology, nano-electronics, nano-technology, nano-fabrication, micro-electro-mechanical systems (MEMS), new materials, biotechnology, and new energy products. Many of them declared that they were impressed by the huge evolution of the cellphone, that even A.G. Bell "couldn't think about this when he invented the phone", and "also surprising is the still poor quality, and how we tolerate it", meaning that owing to some psychological effect, we are available to accept any eventual bad voice quality thanks to our mobility. Assumed that the cell-phone is considered in absolute the symbol of wireless, if we try to have a look into incoming and future perspectives, some of interviewed experts could imagine of "smart intercommunicating everything", or a "distributed sensing, which goes hand in hand with computation capability", or "wireless embedded computing". These phrases seem to indicate that wireless by itself is a technology enabler for many applications, and that combined with other sciences or technologies such as artificial intelligence, pervasive computing, MEMS and micro-systems, it can bring solutions potentially capable to solve many societal problems in the field of health care, safety, industrial and office work environments, transportation (automotive, avionics), environmental control, as many others.

2. WIRELESS PANORAMA

2.1 Wireless Generations and Milestones

The impressive evolution of wireless technology over recent years, has been underlined by a number of technology generations, with their associated features and milestones. Table 1 resumes the most important of them; in particular

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half-generations represent technologies of transition, and will not be considered here. Initially, with the first generation (1G), voice telephony services could be provided for the first time in a wireless fashion. The transmission involved the use of analog modulation (AMPS, TACS), with a poor quality of service, mainly arising from the vulnerability of the modulation scheme to interference and fading. The technology at that time was quite rudimentary, requiring big dimensions for the terminals, and limited autonomy even with very big batteries. With the advent of second generation (2G), more robust digital modulations schemes replaced the old analog ones, and thanks in particular to European efforts on GSM system design and standardization, we have seen a massive introduction of cellular phones in the marketplace. Today cell-phone usage is so widely spread worldwide, that it is not considered anymore a status symbol - as it was at the beginning - but instead a personal effect, and it looks strange now to see somebody not capable of using it.

Generation	Milestone	Features
1G	Voice Telephony, Paging	Analog Modulation (AMPS, TACS)
2G	Voice Telephony and supplementary service (SMS,..)	Digital Modulation (GSM, IS95, IS136)
3G	Multi-media services: audio, video, video-phoning Internet, Web browsing	Digital Packet Network transmission (UMTS, WCDMA, CDMA2000)
4G	ABC = Always Best Connected Integration of UMTS and Wi-Fi in the Cellphone	Seamless roaming among multiple kinds of networks Convergence, interoperability of wireless standards and networks
AmI	Seamless Wireless Networked Environments: human body, home, office, factory, car, …	People and objects bi-directionally connected and communicating

Table 1: Wireless generations with their milestones and features

The third generation (3G) is currently bringing into the market more powerful terminals, that besides the usual voice call service, will offer a large set of multi-media services such as audio (downstream of MP3 files, music), video files, video-calls, and an efficient fast Internet connection with web browsing and email. 3G is considered de-facto as a first step in the transformation of the cell-phone into a new-generation wireless handheld device, which will be our "personal life assistant". From a technical point of view, 3G brings more bandwidth and data rates owing to UMTS, WCDMA, CDMA2000 standards, but also digital packet network transmission, enabling much higher efficiencies in the utilization of the network (cost of the transmitted bit/second/Hertz). As the third generation is smoothly becoming a reality, people start thinking about what's next in the wireless revolution, and new definitions like Beyond-third-Generation (B3G), towards fourth-generation (T4G), or simply fourth-generation (4G) have been introduced. The most often mentioned paradigm for the 4G is "ABC = Always Best Connected", which represents the ultimate goal for a mobile, nomadic user. As the mobile users and the mobile workers are frequently transitioning during their daily journey into different kind of environments (i.e. home→car→train→office→public rooms→car→home), it would be highly desirable that they keep, with their terminal, always the best connectivity, both in terms of cost and quality of service, in the presence of a multitude of available wireless networks. 4G responds to the fundamental need of communicating "anytime, everywhere" with our terminal, irrespective of the environments and available networks (cellular, LAN, DSL,…). 4G will cause a radical change in both cellular networks and terminals designs, as it implies a migration from a network-centric/device specific context, into a user-centric/device agnostic one (concept of "user-centric technology"). At the terminal level, the wireless platforms for hand-held devices will have to evolve into multi-mode, multi-standard architectures, integrating not only cellular modes but also WLAN, cordless, and eventually others. Actually, it is believed that the fundamental milestone of 4G is represented by the integration of WLAN into the cell-phone. New architectures capable to handle this multi-mode capability, are currently explored. Among them, the software radio has been proposed as a possible solution. However, by placing a high-linearity, high-dynamic range but power hungry data converter as close as possible to the antenna to digitize the radio signal, the software radio architecture is optimized in terms of hardware complexity, but is not competitive in terms of dissipation. As a consequence, software radio has been widely recognized as a viable solution for the implementation of multi-standard base station architectures, whilst examples of successful implementations on mobile terminals have not been reported really. In 4G, the concepts of “cognitive radio”, or “context aware” smart terminals are also introduced. Cognitive radio stands for a wireless expert system within the cell-phone, which is capable of optimizing its performance, in terms of quality-of-service and costs of exercise, by running an auto-learning process, on a daily basis, which permits the cell-phone to best adapt to the users needs. The integration of sensors is vital for enabling the concept of context aware terminals. For example, speed or accelerometer sensors in the cell-phone, can disable some transmission modes which are considered dangerous in a given context, like a video-call while driving the car.

Until now, we have quickly described a number of wireless generations, which enable people to communicate and exchange information in a wireless fashion. Another disruptive wireless technology, AmI = Ambient Intelligence, has been recently proposed, whose core idea consists in enabling bi-directional, seamless communications among objects and people, thus allowing the “smart intercommunicating everything”, “distributed sensing”, “wireless embedded computing” scenarios mentioned in the introduction. Ambient Intelligence arises from a right combination of low-cost, short-range wireless technologies, artificial intelligence and pervasive computing. Thanks to an expected large number of applications in the factory, home, office automation, as well as in health care, safety, security, infotainment, and others, AmI is expected to be the next long wave of wireless.

2.2 Wireless Standards

Nowadays we are seeing the introduction of a plethora of wireless standards, addressing a continuously growing number of applications. Wireless standardization activity is relevant, because key subjects such as the spectrum allocation, the quality of service, the electrical performances and other features, are clearly addressed and specified. Equipment vendors and service providers are obliged to fulfill the requirements imposed by the standards; more equipment vendors can join efforts to build up an harmonized offer around a standard, eliminating “a priori” the risk of incompatibility of different subsystems; clients can earn a clear understanding of the system they intend to buy, and can compare among different offers.

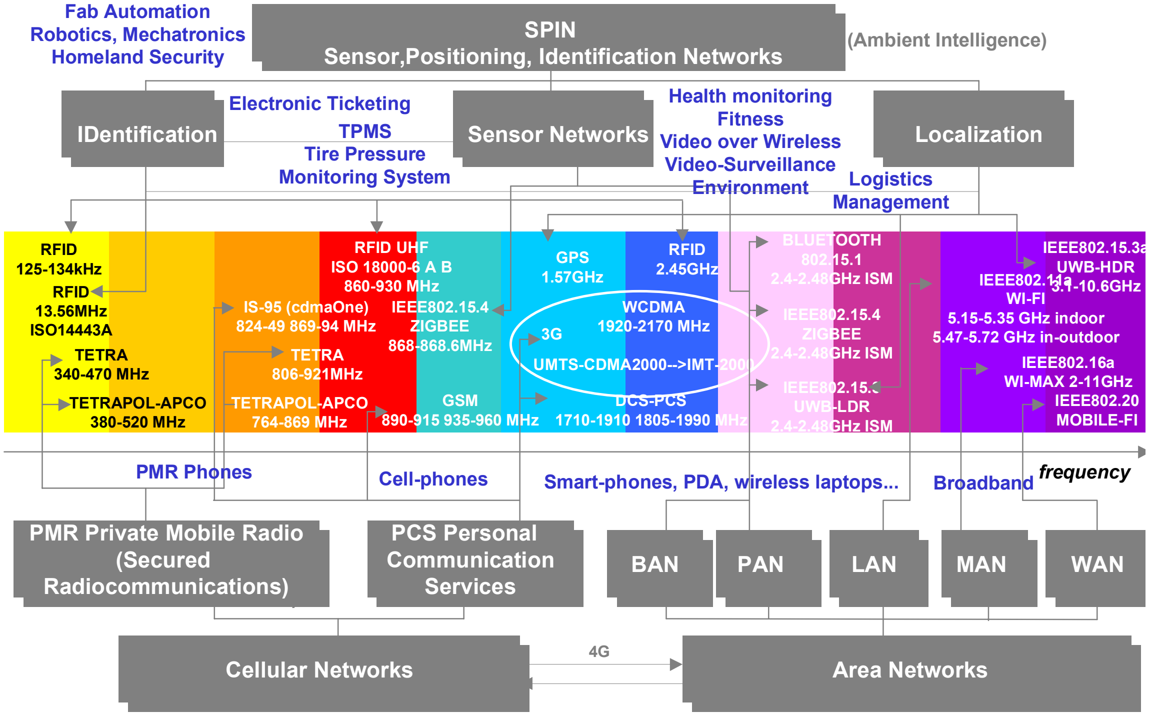

Figure 1. Pictorial view of wireless standards and categories

Since several application scenarios, like the industrial automation, or mobility for emergency and safety applications, due to their complexity, actually require a set of wireless standards to implement the application itself, new high hierarchical level standardization initiatives, tending to "standardize a set of standards" for a given application, are also taking place. For instance, the MESA Project (Mobility for Emergency and Safety Applications), as a joint effort of ETSI in Europe and TIA in United States, envisions a global secured technology (narrowband voice transmission, wideband data transmission, video, localization) tending to serve a wide range of security-emergency sectors, such as firefighting, homeland security, disaster response, and other mission-critical operations [2]. In this sense, MESA project is often defined as a "system of systems", this meaning that a variety of technologies such as PMR, WLAN, 3G, GPS, may be simultaneously needed, embraced and harmonized.

Figure 1 provides a pictorial view of the current situation about wireless standards. The used frequency range is impressive, starting from 125 kHz for low-frequency RFID, up to well beyond 10 GHz for Metropolitan Area Networks (MAN) and Wide Area Networks (WAN), with IEEE802.16a "Wi-Max" and IEEE802.20 "Mobile-FI" standards, respectively. We can recognize three large families, comprising sub-categories: i) Cellular Networks, ii) Area Networks (AN) and iii) Sensing, Positioning, and Identification Networks (SPIN). From an historical point of view, the first commercial applications fall in the first one, with Personal Communication Services (PCS), like cellular GSM, UMTS, cordless DECT, and similar ones. In parallel to PCS, Private Mobile Radio systems (PMR) are gaining momentum, since they address secured radio-communications, a more and more important need in today society. PMR systems are dedicated networks and services, addressing specific needs of special users such as the police force, firefighters, medical personnel, but also private bodies and companies, which find convenient to own or use a private network (airports, big fabrication plants, ..). Some special features of PMR systems are the 100% guarantee of the call, which may be not guaranteed by a standard cellular system in some particular situations - how many of us have experienced the lack of the line during a football match at the stadium -, the priority call, the group call, and the high-level of security of the communication. However, as the cell-phones are evolving into smart-phones, then into our 'personal life assistants', the required level of security in storing (i.e. personal data) and sending information (i.e. transactions), is becoming higher and higher. In this sense, it appears that both PMR and PCS are smoothly converging into secured cellular communications. A second large family of wireless standards consists in Area Networks (AN). From the first successful commercial exploitations, realized with WLAN and its Wi-Fi standard, we assist now to an expansion of the technology from very-short range, with "ad-hoc" Body Area Networks (BAN) and Personal Area Networks (PAN), addressing medical implanted devices, fitness, communications and infotainment, to long and very long ranges, up to citywide and rural coverage, with Metropolitan (MAN) and Wide Area Networks (WAN), and their respective standards IEEE802.16 'Wi-Max", capable to deliver up to 70Mbit/s, and IEEE802.20 "Mobile-Fi". As shown in Figure 1, it should be stressed that cellular networks and area networks technologies have interactions and show convergence into 4G systems.

3. SPIN NETWORKS

3.1 SPIN Application Scenarios

In this Section we will describe the third big family of standards shown on top of Figure 1, SPIN = Sensor, Positioning, and Identification Networks. As the name suggests, SPIN wireless networks distribute i) information and measurements coming from sensors, ii) identification of objects (ID), and iii) their localization (LO). At the top level, we can consider that the technology is capable of transmitting and distributing simultaneously all the three above mentioned categories of information. Several application scenarios require such kind of complexity, like the factory automation, or some defence applications like the homeland security (detection of dangerous materials, their localization, identification of the persons bringing the materials). Other applications require a combination of two of them, like for example the Tyre Pressure Monitoring System (pressure and temperature sensors plus identification), or the logistic management of consumer goods (identification and eventually localization), finally others require the capability of transmission of only one of them, like the RFIDs in applications such as tele-pass, electronic ticketing… SPIN networks can be considered as a high-potential technology for enabling Ambient Intelligence (AmI), and in general for solving or at least alleviating many societal problems.

Figure 2 shows a pictorial view illustrating a number of applications covered by this technology. SPIN networks appear very promising in medical applications, such as health monitoring. It is known that we move into a society where the number of old people will grow significantly; the list of health risks in such age is also well defined, with heart disease, Alzheimer, diabetes on top of it. In the case of heart disease, health monitoring, implemented by a transceiver placed near a pacemaker, or a defibrillator, can help to assist the patient 24 hours per day, without subjecting him to frequent journeys to hospitals. The transceiver not only can be used to monitor the activity of the pacemaker, but can also send alarm signals in case the battery is exhausted, or if the patient has a cardiac attack.

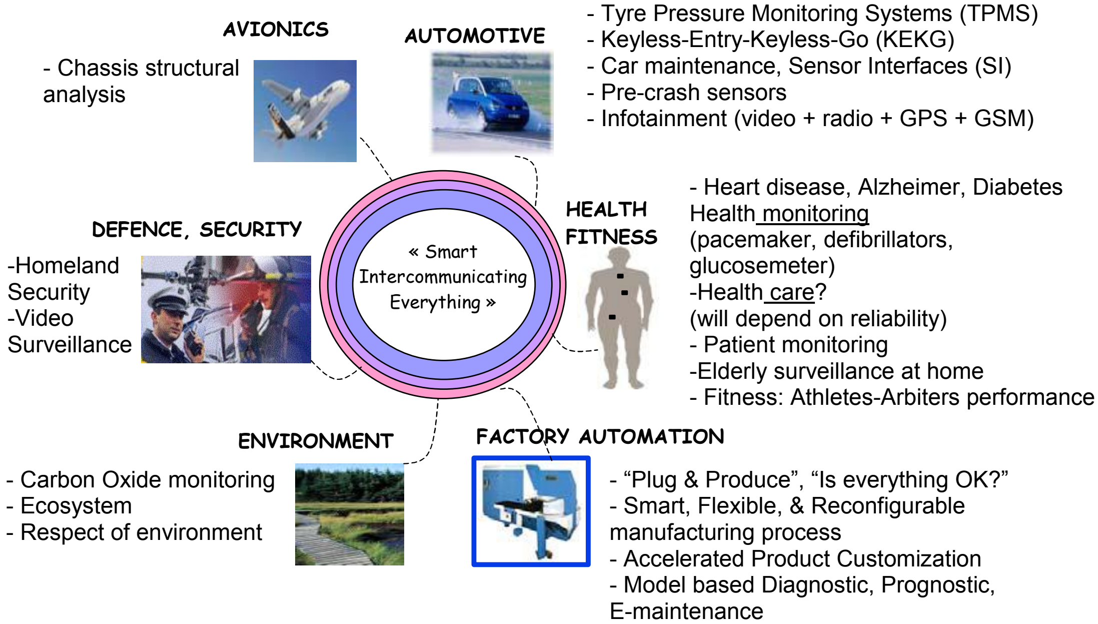

Figure 2. SPIN networks application scenarios

Compared to health monitoring, health care represents an even more advanced application of SPIN networks, since the wireless transmission now takes an active role in the medical treatment of the patient. As a consequence, reliability and quality requirements become obviously much more severe. We can imagine that several implantable devices could be interconnected to form a human Body Area Network (BAN). In that case, they could be used not simply to monitor, but also to treat some disease. In the case of diabetes, for example, it would be possible not only to monitor the patient in a wireless fashion by analyzing the data transmitted by a glucosemeter, but also to inject consequently more or less insulin, still wirelessly. One important aspect of the application in the health sector, is related to the security and privacy of the communication. As the first factor seems obvious, especially in the health care, where any unwanted modification of the data could be harmful, the second one should be also considered, as information on the health status fully belongs to the privacy sphere of people.

Quite similar applications can be devised for fitness, sport. Some very light and wearable wireless devices, could be embedded in the t-shirts of football player, to check the performance and physical status of the athletes (and why not, of the referees…). These smart devices could also indicate the precise position of the players, once the transmitted signal is received, then processed by some hubs located at the border of the sport ground.

Other significant exploitations can be foreseen in defence and security sectors. About defense, homeland security is impressively improving, as a response to the recent terrorist attacks. This year (2005), the U.S department of Homeland Security has received a budget of $ 33.8B from the government, which represents an impressive up-trend. It is predicted that Europe will follow this trend. Some critical zones, like airports, stadiums, public places, could be equipped with a wireless sensor network, capable to detect the introduction of dangerous materials such as bacterial, chemical, nuclear, radio-active substances, and send an alarm signal to a Private Mobile Radio (PMR) network, indicating the kind of material, the localization, and if possible the identification of the person bringing such materials.

Automotive and avionic sectors are also promising applications. About the car sector, some manufacturer leaders recently announced that they will try to remove from the car all electronics which is at the end un-useful and non-related to safety. Recently, a prestigious car manufacturer was proud to announce that it significantly reduced the electronic bill of materials in their cars. SPIN networks keep the promise of introducing new electronic systems enhancing the level of safety of the car. The most promising example in such category of applications, is surely represented by the Tire Pressure Monitoring System (TPMS). Sensor Interfaces (SI) can be also deployed to implement pre-crash detection systems, micro-cameras monitoring dangerous dead zones, which are out of the driver's visual field, and computer assisted maintenance. Other applications include the remote keyless-entry-keyless-go (KEKG) systems, some of them being already deployed in some top-class models in combination with fingerprint recognition, and the infotainment, addressing the wireless networking of electronic systems in the car (GSM + GPS + radio + video). In avionics, a very important application is related to the plane maintenance, and consists in embedding in the plane chassis a network of sensors, capable of measuring, collecting and storing, during the flight, information on pressure, temperature, mechanical stresses, which can be analyzed later on.

3.2 The Smart Factory

Another key application for SPIN networks, which best describes the potential of this technology, is Factory Automation. Large Companies with modern fabrication plants have to compete hard worldwide, not necessarily to be the leaders, but sometimes just to stay on the marketplace. More specifically, there is currently hard competition between Europe and Asia-Pacific regions. The semiconductor market represents perhaps the best example of this situation. If it is true that we see in Asia, and especially in China, Taiwan, Korea, the creation of impressive semiconductor factories, it is also true that Europe is making in parallel huge investments as well. Generally speaking, the manufacturing chain has to stay very efficient, and any second wasted in repetitive tasks, can make a huge difference at the end in getting cost-effective products, with on-time delivery. Moreover, in future scenarios, manufacturing chains of modern fabrication plants, are required to be flexible and configurable, to self-adapt to newer product customizations.

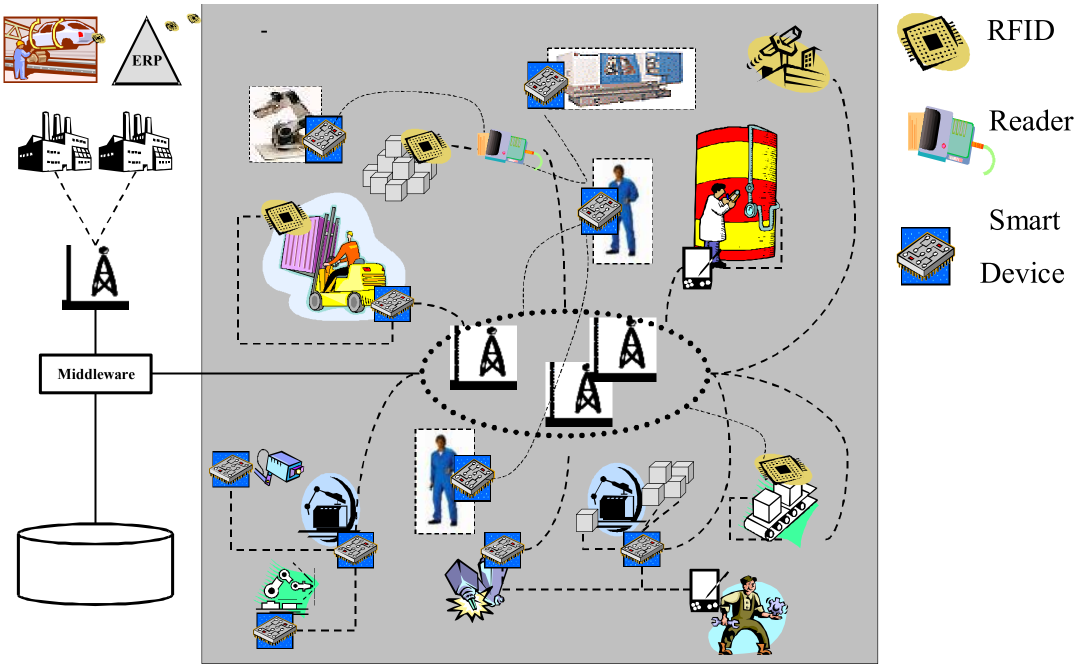

Figure 3. An ideal application scenario for SPIN Networks: the Smart Factory

Figure 3 depicts how a "Smart Factory" should appear, where the fundamental elements of the factory, i.e. machine tools, goods under production, and human beings, are interconnected. Wireless technology is used to collect, distribute, and use real-time information exactly when and where it is required. Today's typical fabrication plants are quite far from this model. For example, machine tools are quite sophisticated by themselves, but they are isolated, and they interact only with the operator. When a new machine tool is integrated in the manufacturing chain, it is not recognized by the manufacturing system. It would be highly desirable to envision the “plug and produce” model, where the new machine tool, provided with an appropriate wireless smart device, is automatically recognized by the production chain and becomes immediately operative after installation. Another fundamental problem of the manufacturing chain is its potential failure, and consequent maintenance strategy. In principle, it may be sufficient that just one element of the chain has a failure, to put out of production the complete manufacturing process, with dramatic economic consequences. The wireless interconnection of all elements would enable the possibility to ask at any moment “is everything OK?” to the production chain. In particular, it would be desirable to predict well in advance a potential machine failure, by monitoring its functional parameters (pressure, force, temperature, vibration, images), and react consequently. Model-based diagnostics is a science capable to detect approaching failures of machines, or products defectivity, by the mathematical analysis of such data. It is evident that a huge number of measurements need to be collected and elaborated, and that wireless technology allows to efficiently transmit from any machine such data into a computer, without the need of having operators physically near the machines. Prognostic is a more advanced concept, based on the idea that by analyzing such data it is possible to correct and optimize the operation of the machines. The maintenance of a manufacturing chain can be a very costly, time-consuming process, also because it is often subcontracted to a different company, specialized in maintenance. Here we could imagine that the embedded wireless smart device of a machine tool under maintenance, controlling the operation of the machine, could be capable to learn from the previous maintenance sessions, on how to best calibrate the machine, in order to improve its “health” performance. This auto-learning process could be made possible, by integrating in the wireless smart device some “intelligent data processing” function, which basically implements an expert system. Some design techniques, such as analog neural networks, are very promising in this field.

The current vision of a Smart Fab is that, contrarily to the past, it should be considered as an open environment, highly interacting with the external world. There are many reasons for this. First, it happens more and more frequently that the whole manufacturing process is not clustered on the same site, but that some specific steps (customizations, packaging, finishing,…) are de-localized. In such situations, it seems obvious to implement an efficient network, linking in-plant with out-of-plant processes. Second, “on-time delivery” of a product is considered by any customer as the global indicator of the quality of the product itself, as well as of the whole Company producing it. In order to succeed in such on-time delivery, it would be an error to isolate the Fab production from the rest of the Company operations. The product designers, the engineers, the customer service, the marketing, the sales forces need to be informed real-time about what’s going on in fab, in order to take the best decisions within the shortest delays. Third, product customizations and e-maintenance are becoming real needs for the factory of the future. Customers may just look for, or even buy, some products (shoes, cars, …) and ask for customizations in a second phase. E-maintenance is also a key factor for a manufacturing company. A computer printer, embedding a low-cost wireless sensor, could transmit vibrational, or other parametric measurements, into a local area network (LAN) of the office where is installed, which would then transmit such information, through internet for example, to the manufacturing plant. The printer Company, thanks to the collection and analysis of a huge number of data coming from the field, would be capable not only to be advised about the potential failure of the printer, thus permitting to readily repair it on the customer site, but also to re-adapt the fabrication process, in case it is concluded that some process step is not well adapted and needs to be corrected.

The basic idea presented in Figure 3 is that all components of the factory are capable to communicate each other through wireless devices. These could range from simple RFIDs, labeling the goods under fabrication, whose ID data could be collected by RFID readers, up to more sophisticated smart devices, installed on the machine tools, or robots, capable to perform measurements, elaborate them locally, exchange such information among them, then transmit to, or receive from, a central station, linked with the Enterprise Resource Planning (ERP) system. Also the human being is linked to the backbone network, through wireless devices with sophisticated man-machine interfaces, like wearable readers, or handheld terminals. For this reason, he is not a passive observer, but he participates to the manufacturing process in an active manner, thanks to the fact that he can analyze real-time information and react consequently. These implications on the potential job evolution of operators, should be not underestimated. Fab operators and technicians could leverage on the wireless technology by avoiding many repetitive tasks, which are cause of errors, and instead concentrating on more added value activities, like the supervision of the manufacturing process.

It might appear that a huge quantity of information, if not processed correctly, could cause the opposite effect, namely blocking the system instead of making it more productive. The best way to describe how a smart fab should naturally behave, according to an Artificial, Ambient Intelligence model, where everything and everybody exactly know what to do next, is to compare the manufacturing process to a football match. During a football match, each football player, from the experience accumulated during previous matches (auto-learning process), from the analysis of the position of the other players, as well as of the ball, and from the suggestions arising from the Coach, is capable to take the best next decision. The football players are the machine and robots, the ball is the item under production, and the Coach is the ERP (Enterprise Resource Planning). SPIN networks, being capable of distributing measurements from sensors, and information on localization and identification of objects (ID), is “the” key technology enabling such scenario.

4. WIRELESS PLATFORMS

Wireless platforms are of great interest for addressing a number of applications in the wireless arena. By definition, they do not necessarily correspond to a final product, but they should be intended as flexible, configurable and customizable HW/SW solutions. According to what was discussed just before, Figure 4 presents a chip-set platform architecture for wireless networks of sensors, particularly tailored to the factory automation. We could imagine that such platform is composed of different functional modules, to be intended as “slots” which can be plugged or removed depending on the required complexity. In this way the platform can cover a number of different devices, from the simplest wireless nodes up to the most complex wireless smart communicative components. Typically, sensor networks for the fab automation are characterized by a quite large number of sensor nodes (hundreds), that should communicate at data rates in the order of tens-hundreds of kbit/second, over short-medium distances (~100m). However, it is not difficult to imagine some situations, like the transmission of images from a camera sensor, for example monitoring the position, speed and acceleration of a robot, where the data rate can grow up and exceed the Mbit/second limit.

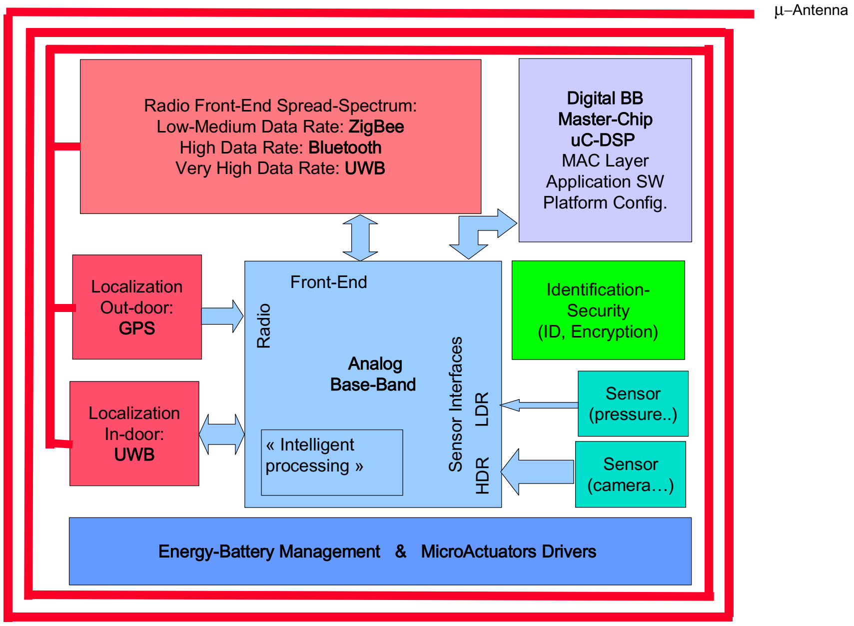

Figure 4. A multi-mode wireless chip-set platform for wireless networks of sensors

In some cases, for security requirements, it may be required that the information should be encrypted before transmission, thus increasing further the data rate. The IEEE802.15.4 standard, with the ZigBee protocol, is considered “de facto” the new emerging standard for this type of applications. It can reach a 250 kbit/s data rate, with a max. distance of circa 30 meters, and can operate worldwide in the ISM unlicensed band of 2.4 GHz. However, Bluetooth appears to be a serious candidate in those applications requiring higher data rates (HDR). In particular, the Bluetooth V2 standard extends the max. data rate from 1Mbit/s up to 3Mbit/s, a more than 10 gain factor in data rate with respect to ZigBee. IEEE802.15.3a UltraWideBand (UWB) technology is also gaining momentum. UWB can offer a very high degree of flexibility, as not only it can deliver very-high data rates, but is also suitable for the fine, indoor localization of objects, a feature which is indispensable in several applications.

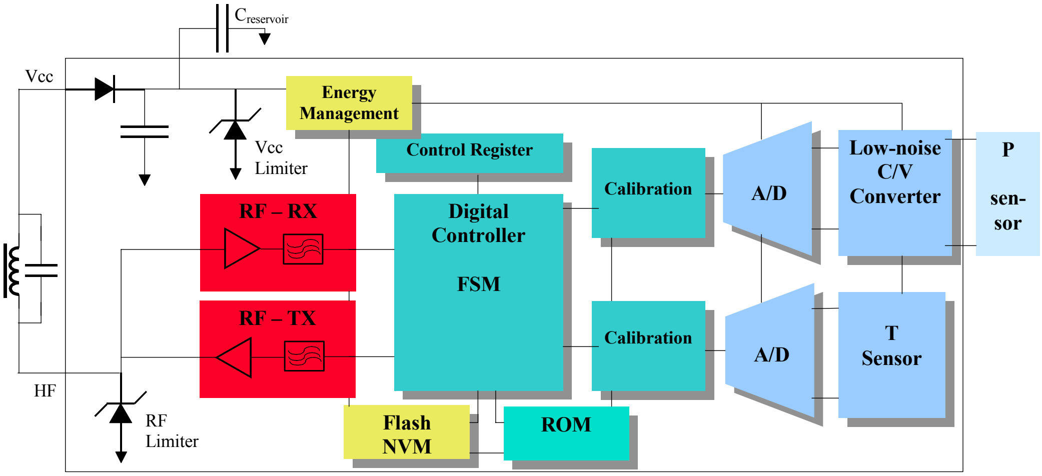

Figure 5. Tyre Pressure Monitoring System (TPMS) smart device

UWB is considered as a disruptive technology, or better, transmission technique. According to FCC, the Federal Communication Commisssion, UWB is any signal that occupies more than 500 MHz BW in the 3.1-10.6 GHz band, and has a spectrum which meets minimum attenuation requirements starting from the hundred MHz (for the indoor communication systems), specified by a spectral mask. According to this definition, UWB is not anymore strictly speaking a technology, as was done in the past by associating it to very sharp impulses, but available spectrum for unlicensed use. Any transmission technique, no matter how is implemented, meeting the requirements, can be considered UWB. The innovative idea behind UWB is the *"spectral overlay*" non-conventional approach, which means that instead of looking for new possible, unsuitable bands, the optimal re-use of the existing spectrum is foreseen, by transmitting very low amount of energy per unit of bandwidth, in order to not interfere with other existing standards. This is made possible by the Shannon law on the channel capacity, stating that a given capacity can be reached also transmitting much less energy per unit bandwidth, if the total channel bandwidth is made higher than the one strictly required to transmit the signal (basic concept of spread spectrum transmissions). In this sense, since there is a very large ratio between the actual channel occupied bandwidth and the minimum required bandwidth, UWB can be considered as an "ultra-spread-spectrum" transmission.

Figure 5 shows one of the best examples of wireless smart micro-systems, the Tyre Pressure Monitoring System (TPMS) transponder. The TPMS device is a complete, autonomous micro-system inside the tyre, which has to transmit both measurements of pressure and temperature, as well as a unique identification number (ID) of the tyre. The device must be capable to manage any collision of transmission with other sources, by proper anti-collision algorithms. The TPMS device, if battery-less, receives the energy wirelessly from a reader during an interrogation phase, preceding the transmission phase. Eventually, the TPMS can be supplied by power scavenging techniques, capable to transform the kinematics energy of the rotating wheel into electric energy. New advanced TPMS devices are continuously under study. For example, it is thought that UWB technique could be used, not only for the wireless data transmission, but also to execute an internal "echo-graph" of the tire, featuring the possibility to detect in advance internal defects, thus preventing a risk of accident.

Before concluding this section, it should be stressed the importance of multi-mode, re-configurable architectures. As discussed before, it happens more and more frequently that an application requires the utilization of different modes or standards. In such cases the availability of re-configurable systems, capable to address different modes, represents a benefit both in terms of cost and level of integration. A common example of multi-mode architecture is represented by the GMS tri-band phone, which actually integrates at least three different LNAs, operating at different frequencies for the three GSM/DCS/PCS frequency bands. Another example of bi-mode architecture is the recent standardization of Adaptive Multi-Rate (AMR) wideband voice codecs, which are capable to deliver both 8 ksample/s toll-grade quality performance, or 16ksample/s enhanced voice quality performance, as demanded by some applications, like Voice over IP (VoIP) or more generally Voice over Packet Networks (VoPN), 3G wireless codecs (

3GPP/ETSI for WCDMA), video-conferencing. Doubling the bandwidth of the transmitted voice signal, results in increased intelligibility and naturalness of speech, giving a feeling of transparent communication.

Figure 6 shows the architecture of the Superstar 3G PMR platform [4,5], which is a silicon chip-set intended for use into multi-mode mobile terminals, capable to operate both in Tetrapol, Tetra, and Apco25 standards. Several special design techniques, like the programmability of digital filters as function of the selected mode, the capability to operate with different master clocks specific to each standard, and the capability to digitize at intermediate frequency (IF) radio signals with very different characteristics, are used in order to achieve multi-mode operability.

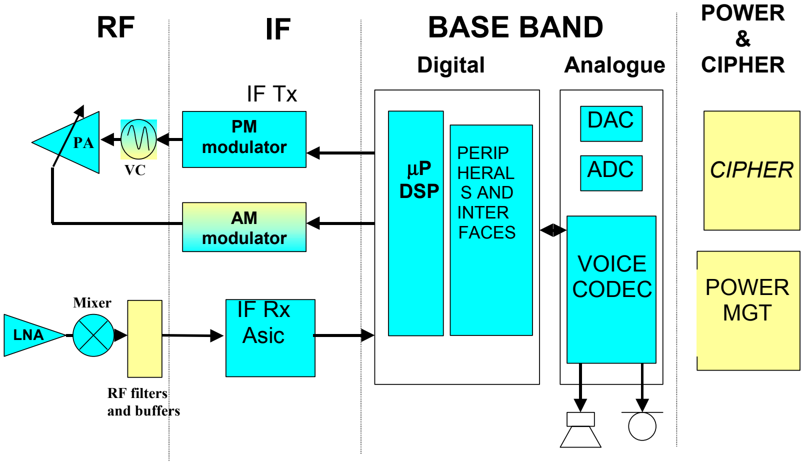

Figure 6. Superstar, a 3G multi-mode PMR platform aiming to operate in Tetra-Tetrapol-Apco standards [4,5]

5. CONCLUSION

In this paper we have presented an overview of the different wireless technologies and their applications. Wireless is seen as one of the most important technologies for the coming decades, with strong perspectives in solving, or at least alleviating many societal problems. The three big families of wireless communication techniques have been identified and discussed: Cellular Networks, Area Networks (AN), and SPIN networks. SPIN networks enable the Ambient Intelligence (AmI) paradigm, which is smart intercommunicating people and objects, and creating an information stream-flow everywhere. They represent the future wave of wireless, where big challenges in reducing the costs, the form factors, and in embedding different technologies, such as artificial intelligence and pervasive computing, will have to be faced. In cellular networks, personal communication systems and private mobile radio are somewhat converging, due to the security requirements of the radio-communication, which is mandatory for PMR, but becomes more and more important also for PCS. Moreover, PMR next-generation systems will tend to exploit, whenever possible, wireless modes which are developed for consumer applications, like Bluetooth, Wi-Fi and Wi-Max. In 4G systems, cellular networks and area networks will be also converging, to realize the “ABC = Always Best Connected” scenario. The general technological challenges of wireless consist in the silicon chip-set horizontal integration, and micro-system vertical integration of heterogeneous components (electronics, micro-antenna, battery, sensors, actuators). In some ultra-low cost applications, like the logistic management of consumer goods, technologies alternative to silicon, like organic electronics, capable to significantly cut the costs of RFID’s, are currently under study and look promising. Multi-mode, multi-standard re-configurable architectures, capable to handle different wireless modes with the same hardware, will become more and more important, as they will significantly contribute to reduce the cost and the form factor of complex micro-devices.

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