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Pervasive Homecare Monitoring Technologies and Applications

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1. Introduction

Research studies and population statistics records indicate that elderly population increases in the developed countries whilst forecasts reveal that 65 and over age group will be nearly 20% of the overall population. One of the major challenges related to this observation is the delivery of homecare and the reduction of healthcare cost without compromising the quality of services provided. Pervasive homecare systems provide information and mechanisms to alert when pathological situations are identified. The implementation of technological solutions for homecare applications minimizes the time to provide help in abnormal situations and improve quality of life in elderly and chronically ills. Pervasive homecare networks provide continuous medical monitoring, control of home appliances, medical data storage and processing and emergency situations awareness. Constant monitoring provides early detection of emergency conditions and assists in optimum scheduling of a wide range of healthcare services for people with various degrees of cognitive and physical disabilities.

Researchers continuously explore technological solutions in order to provide homecare and healthcare services for the elderly, chronically ill and children. The amount of proposals reveal a rapidly growing scientific area of high impact on sensitive groups that significantly improve quality of life and prevent or deal with life threatening situations. However, the use of this wireless sensor technology in medical practice not only allows a supreme level of complexity in patient monitoring with regards to existing parameters (such as vital signs), but also offers the prospect of identifying new ways of diagnosing and preventing disease.

Although wired communication technologies, such us ATM (Asynchronous Transfer Mode) and optical communication, are widely used, the key aspects for pervasive healthcare communication is the transfer of high-speed and ubiquitous health data in every place in earth securely and promptly. Wireless technology came to encompass the e-health monitoring everywhere from any given location, providing the so-called m-health services. Research and development advances in the e-health community include data gathering and transfer of vital information, integration of human machine interface technology into handheld devices, data interoperability and integration with hospital legacy systems and electronic patient records.

However, several major challenges still need to be clarified so as to expand the implementation and use of mobile health devices and services and reinforce the market development. In recent years, there has been increased research on commercial mobile health systems based on WLAN (Wireless Local Area Networks), WiMAX, GPRS (General Packet Radio Service) and 3G UMTS (3rd Generation Universal Mobile Telecommunications System) networking technologies, in conjunction with the improvement of the radio frequency identification (RFID) and wireless sensor technology. These technologies have been utilized in the deployment of emerging healthcare and homecare systems. The introduction of high speed data rate, wide bandwidth, digital and encrypted communication technology, makes possible the delivery of audio, video, health status and waveform data to wherever and whenever needed. It is hoped that the current miniaturization of wireless sensor devices, context-aware and intelligent applications and the deployment 3G-based systems with global operational morphologies will improve some of the limitations of the existing wireless technologies and will provide a well-organized platform for homecare services.

The mission of this book chapter is to provide a comprehensive analysis of the homecare technology, applications and implementation of wireless technologies in the healthcare sector by using in addition case studies to highlight the successes and concerns of homecare projects. There are a variety of applications, devices, and communication technologies emerging in the homecare arena, which can be combined to create a pervasive mobile health system. This study highlights the key areas of concern and describes the various types of applications. An inclusive overview of some of these homecare health applications and research is presented.

The rest of the study is organized as follows; the recent advances in homecare enabling technologies using wireless body sensors and body and personal area networks technologies are discussed in Section 2. The classification of the wireless technologies is illustrated according to their total throughput within the relevant applications following the end-users view. Section 3 aims to describe, review and categorize the wireless sensors depending on the sensor principle, which detects the measurable quantity, the signal processing algorithms of the perceived information, their energy efficiency and categories of health status information. Section 4 describes various applied homecare platforms and case studies, along with their applications and services. A classification of these platforms is prepared in terms of the main focus categories such as fall detection, ambient assisted living, aging and rehabilitation, location tracking and continuous healthcare monitoring, in conjunction with some results and suggestive extensions. A brief discussion and concluding remarks will also be given in Section 5 in succession to the future trends for pervasive homecare delivery.

2. Enabling homecare technologies

Various wireless telecommunication technologies are employed in order to integrate medical applications and networking in unified fields of smart homecare services. Coexistence and cooperation of personal area technologies such as radio frequency identification (RFID), bluetooth, ZiBee and wireless sensor networks with large scale wireless networks such as 3G, Wi-Fi, WiMAX provide complete context-aware homecare applications if high quality services. Several issues concerning the integration of these technologies are open and need to be addressed as the technologies mature. There are various applications and prototypes developed, some of them devoted to continuous

monitoring for cognitive disorders like Alzheimer's, Parkinson's or similar cognitive diseases. The trend of homecare and healthcare services moves from the large scale technologies that provide the medium of data transfer and processing to the small scale devices attached to or even implanted to subjects in order to monitor physiological parameters and provide actuators capabilities in dealing with an acute and life-threatening situation. Some focus on fall detection, posture detection and location tracking and others make use of ambient information to identify patients' health status.

The development of wireless sensor networks (WSN) to monitor patient's physical and biochemical parameters continuously establish a health monitoring system and the specific application of them, the body sensor network (BSN), provides a low cost homecare health monitoring system capable to detect and analyze abnormal situations and even enable the delivery of immediate health services. Focusing on a specific example, BSN homecare health monitoring system is appreciated in heart rhythm abnormalities. A trial fibrillation is encountered in nearly 4% of the population over the age of 60, high blood pressure (hypertension) is one of the most widespread cardiovascular diseases affecting millions of people in the developed countries and heart failure is responsible for hundreds of thousands deaths annually. BSNs offer the chance to diagnose cardiac disorders earlier in risk groups such as elderly as well as the ability to monitor the disease progress and the response to any treatment delivered.

Context information is necessary in homecare monitoring networks because it enables the understanding of the special conditions and provides the framework in which monitored parameters are interpreted in an optimum way. If for example sensors placed in the chest of the subject detect an increased heart rate then the initiation of immediate actions in order to prevent the progress of a tachycardia is controlled by context information gathered by sensing systems that incorporate more than one type of sensing capabilities. The initiation of immediate actions is then decided from the output of a processing stage that uses as input several sensor streams in order to form a clear understanding of the context. The context information enhances the identification of the unusual patterns and making more precise inferences about the situation.

Most of the existing solutions include one or more types of sensors carried by the patient, forming a Body Area Network (BAN), and one or more types of sensors deployed in the environment forming a Personal Area Network (PAN). Data from BAN and PAN are connected via gateway nodes to large-scale networks. A common characteristic in commercially available products or prototypes is the categorization of possible homecare services users (children, elderly and chronically ill, caregivers, healthcare professionals). These groups interact with the BAN and PAN.

One essential issue concerning BAN is the power consumption. There are various proposals for energy efficient MAC protocols but only a few of them are applicable in real situations and can be implemented. The other part of energy consumption problem is related to the energy efficient sensor devices, which is addressed mainly from the development of microelectronics and the implementation of low power consumption devices. Technologies used to form BANs exclude Bluetooth and Wi-Fi since these technologies offer only a few weeks runtime if energy efficient protocols are implemented. Some of the issues addressed in this chapter are the technologies used to implement BANs, some case studies with sensor nodes sampling biosignals such as electrocardiogram and respiration signal and the energy consumption problem where theoretical, simulation and measurements are provided in order to establish a basis for optimum radio transmission use since the radio subpart of the BAN nodes is considered to be the most energy consumable part.
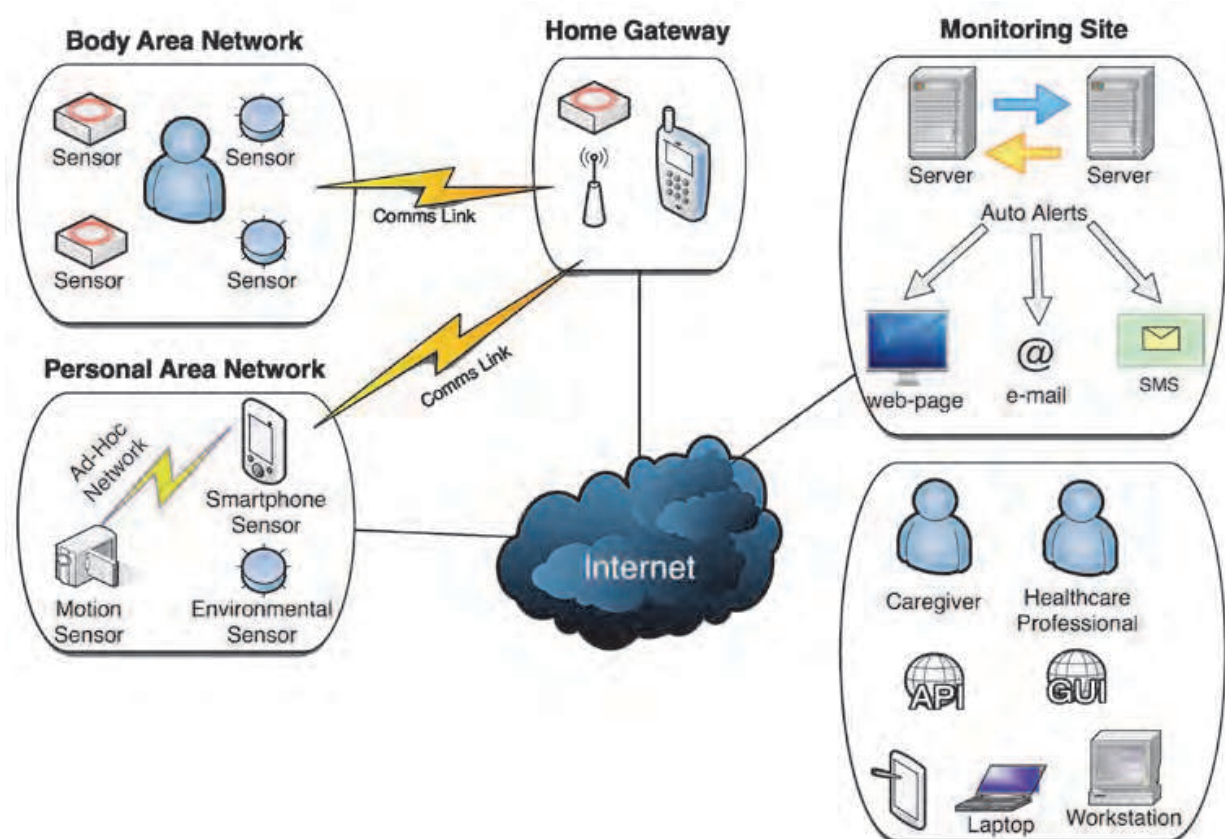
Fig. 1. Simple BSN - PAN application scenario for homecare monitoring application

Personal area networks are composed of environmental sensors deployed around and mobile or nomadic devices. Environmental sensors like RFIDs, video cameras, sound sensors, temperature and humidity sensors provide contextual information. Location information is possible to be provided by this category of sensors.

The gateway subsystems connect BAN and PAN subsystems to the Wide Area Networks (WAN) and mobile devices carried by the user or sensor nodes with WAN interfaces implement it. Local processing capabilities at the BAN and PAN subsystems have a significant effect on network congestion in the gateway. Therefore the processing of information gathered by the BAN and PAN is proved to be necessary (as it is stated in numerous research papers) before transmitted in the WAN. The gateway can relay information to one or more network systems depending on the application. Wide area networks can be cellular networks, ordinary telephone network, satellite networks or even internet.

3. Wireless sensor standards and homecare concerns

A basic issue concerning communication is the choice between the transmissions of real time multimedia, electronic health record and biosignals data and the "Store and Forward" method with implies asynchronous communication. In this section, a detailed description of the available wireless sensor standards is prepared and the related homecare technology considerations for the design and implementation of such systems are presented.

3.1 Sensor standards

One of the critical requirements in wireless sensor networks is the low power consumption, which sets the constraints in the wireless sensors standard development and provides the interfaces to other network technologies. Some of these standards include IEEE 802.15.4 [1], ZigBee [2], WirelessHART [3] ISA100.11 [4], IETF 6LoWPAN [5][6] IEEE 802.15.3 [7], Wibree [8], IEEE 802.15.1, Medical Implant Communications Service (MICS) [18], Wireless Medical Telemetry Service (WMTS) [19].

3.1.1 IEEE 802.15.4

The main standard for low rates WPAN is IEEE 802.15.4 with the main characteristics of low complexity, low cost deployment and low power consumption. Battery lifetime is maximized in wireless sensor networks compliant with IEEE 802.15.4. Topologies supported are star and peer-to-peer between devices either via a network controller or via adhoc links. IEEE 802.25.4 defines the two lower layers, namely the physical and MAC layer. In the physical layer 868/915 MHz bands are supported as well as 2.4GHz band whilst in MAC layer access is controlled using the CSMA/CA mechanism. In MAC layer network synchronization, device association and frame validation and delivery are implemented.

The physical layer (PHY) ultimately provides the data transmission service, as well as the interface to the physical layer management entity. PHY manages the physical RF transceiver and performs channel selection and energy and signal management functions. It operates on one of three possible unlicensed frequency bands (Table 1):

- 868.0-868.6 MHz: Europe, allows one communication channel (2003, 2006)
- 902-928 MHz: North America, up to ten channels (2003), extended to thirty (2006)
- 2400-2483.5 MHz: worldwide use, up to sixteen channels (2003, 2006)

The original 2003 version of the standard specifies two physical layers based on direct sequence spread spectrum (DSSS) techniques: one working in the 868/915 MHz bands with transfer rates of 20 and 40 kbit/s, and one in the 2450 MHz band with a rate of 250 Kbit/s. The 2006 revision improves the maximum data rates of the 868/915 MHz bands, bringing them up to support 100 and 250 Kbit/s as well.

Beyond these three bands, the IEEE802.15.4c study group is considering the opened bands 314-316 MHz, 430-434 MHz, and 779-787 MHz bands in China, while the IEEE 802.15 Task Group 4d is defining an amendment to the existing standard 802.15.4-2006 to support the new 950 MHz-956 MHz band in Japan. First standard amendments by these groups were released in April 2009. In August 2007, IEEE 802.15.4a was released expanding the four PHYs available in the earlier 2006 version to six, including one PHY using Direct Sequence Ultra-wideband (UWB) and another using Chirp Spread Spectrum (CSS). The UWB PHY is allocated frequencies in three ranges: below 1 GHz, between 3 and 5 GHz, and between 6 and 10 GHz. The CSS PHY is allocated spectrum in the 2450 MHz ISM band [9]. In April 2009 IEEE 802.15.4c and IEEE 802.15.4d were released expanding the available PHYs with several additional PHYs: one for 780 MHz band using O-QPSK or MPSK [10], another for 950 MHz using GFSK or BPSK [11].

It is the basis for the ZigBee, WirelessHART specification, each of which further attempts to offer a complete networking solution by developing the upper layers which are not covered by the standard. Alternatively, it can be used with 6LoWPAN and standard Internet protocols to build a Wireless Embedded Internet. The basic framework conceives a small distance communications range with a transfer rate of 250 Kbit/s.

For low cost and low complexity purposes, IEEE 802.15.4 defines Reduced Function Devices (RFD) and Full Function Devices (FFD). RFDs implement a subset of IEEE 802.15.4 and cannot act as coordinator. FFDs have a full implementation of the standard. Any IEEE 802.15.4 compliant radio is capable of performing three different signal power measurements, Link Quality Indication (LQI), Energy Detection (ED), Clear Channel Assessment (CCA).

Frequency Bands	Coverage	Channels	Data Rate	Data Modulation	Chip Modulation
2.4 GHz	Worldwide	16	250 kbit/s	16-ary orthogonal	OQPSK, 2 Mchips/s
868 MHz	Europe	1	20 kbit/s	BPSK	BPSK, 300 kchips/s
915 MHz	Americas	10	40 kbit/s	BPSK	BPSK, 600 kchips/s

Table 1. IEEE 802.15.4 Frequency Bands, Data Rates and Modulation Techniques

3.1.2 ZigBee

ZigBee defines the higher layers of communication protocols on top of IEEE 802.15.4 standard for low rate personal area networks. It was developed by the ZigBee Alliance with the ambition of enabling reliable, cost-effective, low power and wirelessly networked monitoring. Primal targets of ZigBee are long battery life, advanced networking capabilities, reliability and low cost.

ZigBee devices can form mesh networks connecting high number of devices together. There are three types of ZigBee devices: ZigBee Coordinator, ZigBee router, and ZigBee end device. The ZigBee Coordinator is the IEEE 802.15.4 PAN coordinator. ZigBee router is a IEEE 802.15.4 Full Function Device (FDD) that participates in a ZigBee network and is not the ZigBee coordinator but may act as a coordinator if needed. A ZigBee router is capable of routing massages between devices and supporting device associations. ZigBee end device is a IEEE 802.15.4 Reduced (RFD) or FFD that participates in a ZigBee network and is neither the ZigBee coordinator nor a ZigBee router. The end device consists of the sensors, actuators, and controllers that collects data and communicates only with the router or the coordinator.

ZigBee builds a Network Layer and an Application Layer on the IEEE 802.15.4 defined layers. The PHY layer provides the basic communication capabilities of the physical radio, while the medium access control layer provides services to enable reliable single hop communication links between devices. The network layer provides routing and multi hop functions for different network topologies. The application layer includes an Application Support (APS) sub-layer, the ZigBee Device Object (ZDO) and the ZigBee applications defined by the user or designer. ZDO is responsible for overall device management and APS provides servicing to both ZDO and ZigBee applications.

3.1.3 IEEE 802.15.1

The Bluetooth SIG, as a medium-rate standard used for short-range wireless communications worldwide, developed IEEE 802.15.1. IEEE adopted and converted

Bluetooth V1.1 specifications into an IEEE Standard, which was officially released in June 2002 [12]. In addition an IEEE 802 Logical Link Control interface was included in order to make Bluetooth a real member of the IEEE 802 family of communication standards as well as the addition of SDL (Specification and Description Language) material.

Bluetooth supports up to seven simultaneous wireless links at a peak data rate of 720 kbit/s over a maximum distance of some decades of meters. Link layer security is supported. All the properties mentioned in IEEE 802.15.1 Bluetooth protocol stack are defined by the specification.

Bluetooth operates in the 2.45GHz ISM frequency band. This band is split into 79 (USA, Europe) or 23 (Japan) RF channels of 1MHz each, in which a Gaussian Frequency Shift Keying (GFSK) modulation scheme is used. It is achieved maximum raw bit rate of 1 Mbit/s per RF channel. Bluetooth devices can be classified into three different power classes: Class 1 with a maximum transmitted power of 20 dBm; Class 2 with a maximum transmitted power of 4 dBm (nominal 0dBm); Class 3 with a maximum output power of 0dBm. Accordingly it varies the effective range of communication. Relevant regulatory rules are set forth in FCC 15.247 (US) and ETSI 300.328 (EU).

IEEE 802.15.1 functions with a spectrum-spreading technique called Frequency Hopping (FH). A Bluetooth radio transmits in the whole 2.45 GHz ISM band, but at a certain instant only one of the available 1-MHz RF channels is used. When a frequency hop occurs, the centre transmission frequency switches to that of another channel.

3.1.4 IEEE P802.15.3

The scope of IEEE 802.15.3 development was to enable quick high load data transfers within a WPAN, e.g. the transmission of multimedia files, and even high-definition video transmission (around 20 Mbit/s) by means of a low-power and low-cost wireless system. Therefore, new MAC and PHY specifications aiming at high data rates for fixed, portable and moving devices within a personal operating space were created [13].

IEEE 802.15.3 MAC and PHY features [14] are: data rates of 11, 22, 33, 44, and 55 Mbit/s over a 2.4 GHz ISM radio link, a MAC protocol that supports asynchronous and Quality-of-Service (QoS) isochronous data transfers and that is partially based on HiperLAN/2, a security suite and ad-hoc peer-to-peer networking, where wireless devices dynamically become master (Piconet Controller) or slave (Device) according to the existing network structure. The IEEE 802.15.3 MAC layer supports secure and non-secure data frames.

The current IEEE 802.15.3 PHY layer operates in the 2.4 GHz band, occupying 15 MHz of RF bandwidth per channel. Hence, three or four non-overlapping channels can be accommodated within the available 83 MHz of the 2.4 GHz band. Relevant regulatory rules are set forth in FCC 15.249 (US) and ETSI 300.328 (EU).

High-rate WPAN chooses a single-carrier PHY in an effort to reduce complexity and power drain. Rather than employing spread-spectrum techniques, the original IEEE P802.15.3 PHY uses Trellis-Coded Modulation (TCM) with multi-bit symbols at 11 MBaud and achieves 11 to 55 Mbit/s peak data rate over a range of some decades of meters.

An alternate IEEE 802.15.3 PHY layer was developed leading to the inception of IEEE P802.15.3a. Ultra wide band became an emerging technology and Multiband-OFDM proposed by the MultiBand OFDM Alliance appeared leaving IEEE 802.15.3a behind with an unclear future.

3.1.5 WirelessHART

The WirelessHART [15] standard provides a wireless network communication protocol for process measurement and control applications. It uses IEEE 802.15.4 compatible radios operating in the 2.4 GHz Industrial, Scientific, and Medical radio band (ISM). The radios employ DSSS technology and channel hopping. It is TDMA synchronized and provides latency-controlled communications between devices on the network.

Power management options enable the wireless devices to be more energy efficient. WirelessHART is designed to support mesh, star, and combined network topologies. A WirelessHART network consists of wireless field devices, gateways, process automation controller, host applications, and network manager. Each device in the mesh network can serve as a router for messages from other devices. This extends the range of the network and provides redundant communication routes to increase reliability.

The process automation controller serves as a single controller for continuous process. The network manager configures the network and schedule communication between devices. It also manages the routing and network traffic. The network manager can be integrated into the gateway, host application, or process automation controller.

3.1.6 ISA100.11a

ISA100.11a supports low data rates wireless monitoring and process automation applications. It is an open wireless networking technology standard developed by the International Society of Automation (ISA). It defines the specifications for the OSI layer, security, and system management. The standard focuses on low energy consumption, scalability, infrastructure, robustness, and interoperability with other wireless devices. ISA100.11a operates in 2.4 GHz radio band; it supports channel hoping and takes care for interference minimization.

3.1.7 6LoWPAN

6lowpan is an acronym of IPv6 over Low power Wireless Personal Area Networks. It enables IPv6 packets communication over an IEEE 802.15.4 based network. Low power device can communicate directly with IP devices using IP-based protocols. 6lowpan is the name of a working group in the internet area of the IETF. The 6lowpan group has defined encapsulation and header compression mechanisms that allow IPv6 packets to be sent to and received from over IEEE 802.15.4 based networks.

Address management mechanism handles the forming of device addresses for communication. 6LoWPAN is designed for applications with low data rate devices that require Internet communication.

3.1.8 Wibree

Wibree, also called "Baby Bluetooth," is a low-power wireless local area network (WLAN) technology that facilitates interoperability among mobile and portable consumer devices such as pagers, personal digital assistants (PDAs), wireless computer peripherals, entertainment devices and medical equipment. Wibree is a wireless communication technology designed for low power consumption, short-range communication, and low cost devices.

Wibree operates on 2.4 GHz and has a data rate of 1 Mbit/s. The linking distance between the devices is 5–10 m. Bluetooth–Wibree utilizes the existing Bluetooth RF and enables ultra-low power consumption. Wibree was released publicly in October 2006.

	Bluetooth	**Wibree**	**ZigBee**
Band	2.4 GHz	2.4 GHz	2.4 GHz, 868 MHz, 915 MHz
Antenna/HW	Shared		Independent
Power	100 mW	~10 mW	30 mW
Target Battery Life	days – months	1-2 years	6 months – 2 years
Range	10-30 m	10 m	10-75 m
Data Rate	1-3 Mbit/s	1 Mbit/s	25-250 kbit/s
Component Cost	$3	Bluetooth + 20¢	$2
Network Topologies	Ad-hoc, point-to-point, star	Ad-hoc, point-to-point, star	Mesh, ad-hoc, star
Security	128-bit encryption	128-bit encryption	128-bit encryption
Time to Wake and Transmit	3 s	TBA	15 ms

Table 2. Feature comparison of Bluetooth, Wibree and ZigBee [16]

3.1.9 Medical Implant Communications Service (MICS)

The MICS is an ultra-low power, unlicensed, radio service available worldwide for implanted medical devices, such as cardiac pacemakers and defibrillators. Licensing is not required. Maximum radiated power in the frequency band from 402-405 MHz is 25 μW, with 25 kHz channel spacing. Therefore, the coverage of MICS is approximately 1-2 meters.

3.1.10 Wireless Medical Telemetry Service (WMTS)

The MICS is an ultra-low power, unlicensed, radio service available worldwide for implanted medical devices, such as cardiac pacemakers and defibrillators. Licensing is not required. Maximum radiated power in the frequency band from 402-405 MHz is 25 μW, with 25 kHz channel spacing. Therefore, the coverage of MICS is approximately 1-2 meters.

3.2 Sensors measurement range

Sensors are the front-end of sensor networks nodes that collect signals. They fall into three main categories. Physiological sensors measure ambulatory blood pressure, continuous glucose monitoring, core body temperature, blood oxygen, and signals related to respiratory inductive plethysmography, electrocardiography (ECG), electroencephalography (EEG), and electromyography (EMG). Biokinetic sensors measure acceleration and rotation caused by human activity. Ambient sensors measure environmental phenomena such as humidity, temperature and provide the context along with biokinetic sensors for captured data interpretation.

Particularly in wireless sensor networks designed for homecare and healthcare applications, sensors are few, heterogeneous and require specific placement. Ineffective placement may lead to serious degradation of captured data interpretation.

Commercial sensors exhibit a wide range of power supply requirements, calibration parameters, output interfaces, and data rates. In typical healthcare or homecare sensor application scenarios, the energy consumption of wireless sensor networks nodes is dependent on sampling and type of signal acquired. Fig. 2. presents energy consumption and data rates across a sampling of commercial systems for continuous monitoring application.
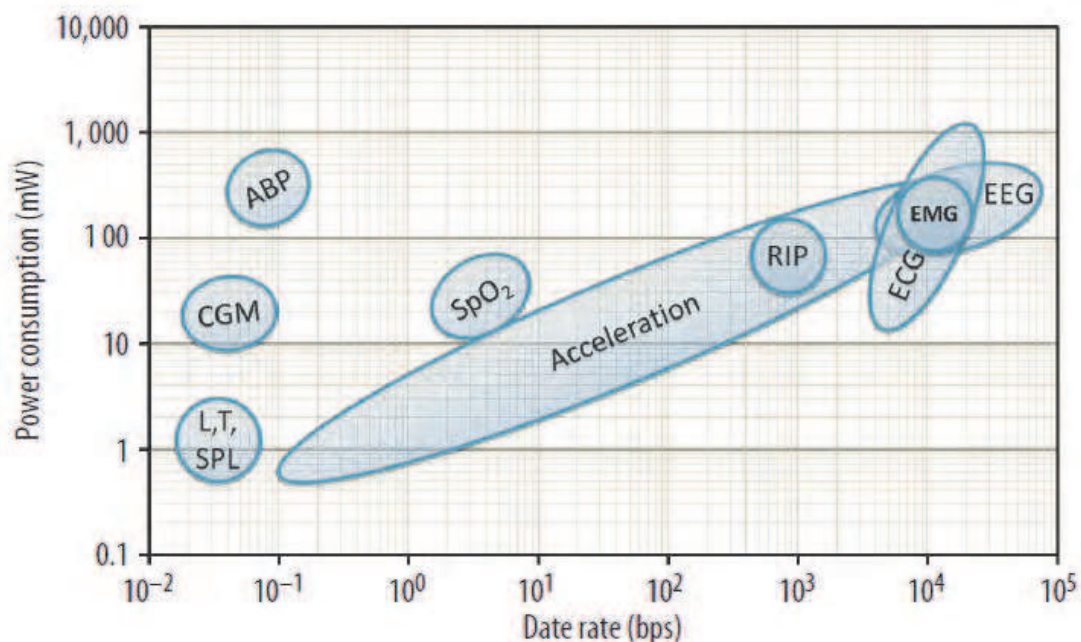
Fig. 2. Average Power Consumption of continuous monitoring applications [17]

3.3 Signal processing

Signal processing is needed to extract valuable information from captured data related with transient signals or events, such as biosignals. It is desirable to rely on sensors with redundant or complementary data to maximize the information content and reduce both systematic and random errors. Additionally the combination of information facilitates the processing and signal analysis stage to extract necessary information from a wide variety of captured data representing time series related to the physical processes monitored.

Whilst the use of multiple identical sensors for error minimization is easily understood, different sensors employment in terms of both sensing type and location requires pattern recognition techniques and machine learning. In practice, the use of multiple sensors with information fusion many advantages compared to single sensor systems, such as improved signal to noise ratio (SNR), robustness and reliability, extended parameter coverage.

The integration of information from heterogeneous networks and sensors reveal the need for multi sensor fusion. In general, the nature of information interaction involved in sensor fusion can be classified as competitive, complementary, and cooperative fusion [20][21].

In competitive fusion, each sensor provides equivalent information about the physical process. It typically involves the handling of redundant, but sometimes inconsistent, measurements. In complementary fusion, on the other hand, sensors do not depend on each other directly as each sensor captures different aspects of the physical process. The measured information is merged to form a more complete picture of the phenomenon. In cooperative fusion, sensors work together to provide information that is not obtainable by any of the sensors alone [22].

Processing data at a given rate consumes less power on average than transmitting same data wirelessly, and data rate reduction reduces power consumption for both wireless transceivers and microprocessors [17][23]. Results indicate a significant reduction of energy consumption at applications, which implement RF transceiver management, and on board signal processing, verifying the well-established belief of trading off radio communication

with signal processing. The limited resources of wireless sensor network nodes especially in processing power define the constraint of this trade off. On-node signal processing will consume power to extract information, but it will also reduce in-network data rate and power consumption. Fig. 3 shows the power consumption of wireless transceivers and microprocessors in popular BASN and WSN platforms.
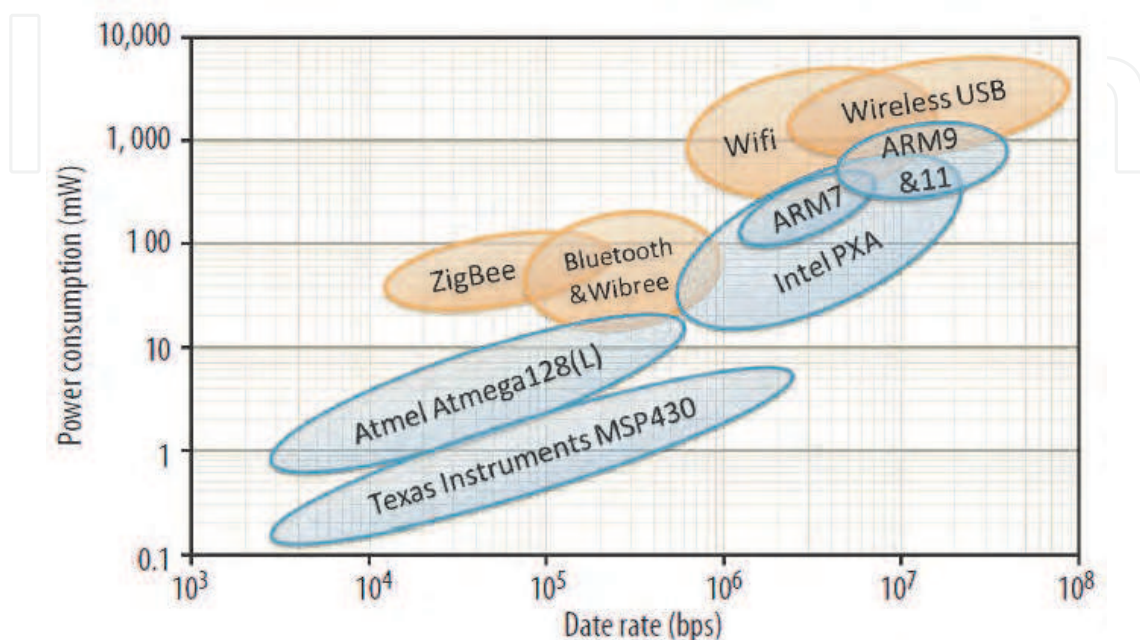

Fig. 3. Average power consumption of wireless transceivers and microcontrollers in Wireless Sensor Networks [22]

3.4 Energy efficiency

As sensor nodes are generally battery-powered devices, the critical aspects to face concern how to reduce the energy consumption of nodes, so that the network lifetime can be extended. The energy breakdown heavily depends on the features of specific nodes. Despite the fact that node's subsystems may differ significantly there are some remarks that generally hold and have well documented in literature as well.

The communication subsystem has energy consumption much higher than the computation subsystem. It has been shown that transmitting one bit may consume as much as executing a few thousands instructions [24]. The radio energy consumption in transmitting, listening mode, idle state is much higher than in sleep state mode of the radio transceiver. Therefore the radio should be put to sleep when possible. Sensory subsystem is another significant source of energy consumption.

Several approaches are employed in order to reduce energy consumption. At a very general level, they are identified in three main categories, namely, duty cycling, data-driven approaches, and mobility.

Duty cycling is mainly focused on the networking subsystem. The most effective energy-conserving operation is putting the radio transceiver in the (low-power) sleep mode whenever communication is not required. Ideally, the radio should be switched off as soon as there is no more data to send/receive, and should be resumed as soon as a new data packet becomes ready [25].

Data-driven approaches impact on sensor nodes' energy consumption in two ways. In the first way sampled data generally have strong spatial and/or temporal correlations, so there is no need to communicate the redundant information to the sink. In the second way the energy consumption is focused on the sensing subsystem. If it is energy consumable then the reduction of radio communication subsystem usage is not enough.

In case some of the sensor nodes are mobile, mobility can finally be used as a way to reduce energy consumption. In a static sensor network packets coming from sensor nodes follow a multi-hop path towards the sink(s). Thus, a few paths can be more loaded than others, and nodes closer to the sink have to relay more packets so that they are more subject to premature energy depletion [26]. If some nodes are mobile then ordinary stationary nodes can save energy because path length, contention and forwarding overheads are reduced. In addition, the mobile device can visit the network in order to spread more uniformly the energy consumption due to communications.

Batteries are currently used for powering most wireless devices. Where the power requirements are modest, primary batteries are usually chosen for their higher energy densities, lower leakage rates and low cost. A lifetime of one year with a few µW as a likely power requirement corresponds to 32 J per µW of average power. Lithium based primary batteries typically provide 1400–3600 J/cc [27], so, in principle, a lifetime of several years is achievable for a battery well below 1 cc. Thus, although the finite lifetime remains a disadvantage other additional issues (such as operating temperature range and toxicity) may reduce their practicality for homecare and healthcare network applications, primary batteries remain a very attractive source for sensor nodes.

Energy sources available in the sensor nodes' environment have been investigated to some degree for energy scavenging applications. The main categories include motion and vibration, airflow, temperature differences, ambient electromagnetic fields and light and infrared radiation. Solar cells provide an excellent solution.

If scavenging methods are successfully exploited, they are likely to be supplementary to, rather than a replacement for, battery technologies. The need for integrated power conditioning circuits with energy scavenging also encourages a trend towards intelligent energy modules, possible incorporating several forms of scavenging as well as storage, power conditioning, and power management electronics.

3.5 Health status information

Homecare and healthcare applications of wireless sensor networks improve the existing monitoring capabilities especially for the elderly, children and chronically ill. Such pervasive systems allow the monitoring of daily living activities, fall and movement detection, location tracking, medication intake monitoring and medical status monitoring.

In the first category the applications with the appropriate equipment identify the status of patients and particularly to distinguish the type of activity taking place (sleeping, walking, running, etc). In the second category the applications are focused on the identification of posture and possible fall detection and alarm for further actions. Location tracking and the medication intake reminder and monitoring systems can help cognitively impaired people to survive independently. Medical care applications make use of medical and environmental sensors in order to obtain comprehensive health status information of the patients, including ECG, heart rate, blood pressure, skin temperature, and oxygen saturation.

4. Homecare platform systems and case studies

In the literature several prototypes and commercial applications exist for pervasive homecare monitoring purposes Medical care applications make use of medical and environmental sensors in order to obtain comprehensive health status information of the patients, including ECG, heart rate, blood pressure, skin temperature, blood glucose and oxygen saturation. Hereinafter, the main categories include (i) fall detection, (ii) complete ambient assisted living, (iii) aging and rehabilitation, (iv) location-based health monitoring, and (v) continuous homecare monitoring.

4.1 Fall detection

Fall detection concept for pervasive healthcare monitoring is quite new employed method for elderly, children and chronically ill people. Movement detection applications give attention to physiological conditions for the people who need special care in case of sudden fall. Information regarding the human movement and activity in assisted environments is frequently acquired through visual tracking of the patient's position, body posture and walk analysis. In the literature, regarding fall detection applications, the researchers are making use of accelerometers, gyroscopes, and tilt sensors for movement tracking, as well as image or video recognition for patient fall incident detection.

There are significant related research endeavor in the field regarding formulas, applications, integrated systems, which may be retrieved from the literature; selected research work of them can be found in [28][29][30]. The most typical applications consider the placement of the patient along with the time of his/her occupation in rooms can be detected from the collected data of the accelerometers. These data can be used in order to verify and detect abrupt movement that could be associated with the fall or other normal and abnormal events. Detection is performed using predefined thresholds and association between current position, movement and acceleration. These systems generally use a 3-axis accelerometer to identify the human placement and movement. Also, base stations can gather the information from the accelerometer and the relayed sensors, and the data can be further processed using signal processing techniques identifying unusual behavior. The most important parameter in such techniques is the discrimination between the actual fall and fall-like situations like lying down, jumping, sitting quickly down on a chair and going up or down the stairs. Advanced algorithms have been introduced so as to distinguish falls and daily living activities [31].

For indoor environment homecare monitoring there are several kinds of sensors that integrate devices like accelerometers, gyroscopes, contact sensors and microphones. These sensors are small, lightweight and embed wireless transceivers, allowing patients and especially elderly people to move freely in the rooms and transmit collected movement and audio information to monitoring units, like access points, wirelessly. An additional sensor category is area sensors that have been used in order to track and analyze patient movement. Particularly, in [32] a system is described utilizing vibration-based detector that can detect falls based on the vibration caused on the floor. Also, in [33], infrared sensors are used in order to provide thermal information regarding the patient's location and movement. The last two approaches depend less on issues like patient physiology and more on environmental information and can be used for a variety of techniques enabling user activity recognition.

On body sensors can also be used in combination with image sensors and video capture equipment. Image sensors detect the position of the patient and a sudden fall can be verified

through image processing analysis [34]. Monitoring methods that need special equipment to be installed on site are, among others, are the overhead tracking of the patient through cameras in indoor locations, which provides the movement trajectory and gives information about the user activity on predetermined monitored areas. Unusual inactivity (e.g., continuous tracking of the patient on the floor) is interpreted as a fall. Correspondingly, omni-camera images are used in order to determine the horizontal placement of the patient's body on the floor in case of fall. For the latter work, the fall detection gives accurate results at 81%.

An alternative method for homecare monitoring of falls and body movement is sound processing. In previous works [35], advanced classification techniques and Kalman filtering for producing more accurate results are presented for a patient fall detection system based on such body sensors. Most of the related work in this context focuses on collecting and analyzing sound data captured from the patient's close environment. Authors in [36] present a sound analysis system enabling the detection of special sounds and their association with events related to specific activities or situations where first aid is needed (e.g., falls, glass breaking, call for help, etc). The examined sounds are categorized into classes according to their corresponding average magnitude levels in order to detect a variety of sound signatures of both distressful and normal events. The aforementioned methods are based on acquisition and processing of sound data that originates from user's monitored environment. A different method has been proposed [37] for detecting patient suffering situations utilizing sounds captured by microphones attached on body sensors and spectrogram analysis sound processing. This technique has provided satisfying accuracy in detecting body fall sounds and distress speech expressions, while it was proved more tolerant to background noise and sounds not originating from the patient.

A configuration of an integrated system for fall detection is illustrated in Fig. 4 [38]. The system comprises of on-body sensors, microphones, accelerometers, video cameras, wireless nodes and wireless pulse oxymeter. The on-body sensors collect specific physiological data (e.g., ECG and blood oxygen saturation) accelerometer and sound data that are transmitted wirelessly to the monitoring node. At the same time, camera devices record video frames from the user's site and provide feed to the video tracker. The latter, tracks the movement of the patient's body and generates body shape features. Based on a predefined classification model, like a train model, the patient status is detected (i.e. emergency status when fall detected, normal status otherwise). Arterial pressure and blood oxygen saturation level are wirelessly transmitted to the monitoring unit from the device. The device has an embedded sound alarm mechanism that can notify caregivers in case predefined thresholds for arterial pressure and oxygen levels are exceeded.

Apart from the indication of a fall incident, an important scope is the estimation of the severity of the incident, which can be extracted by the patient's behavior after the fall. Therefore, ontologies have been used to model the patient's status and context, while proper rules evaluation provides the severity estimation. Both sensor and normal visual activity can indicate that patient has recovered from fall, and no activity at all can indicate higher severity of the incident. One method called body video tracker and is able to provide across time the frame regions occupied by human bodies. The tracker is built around a dynamic foreground segmentation algorithm [39] that utilizes adaptive background modeling. One step ahead, is the Incident Severity Estimation. This can be accomplish by introducing Semantic Representation and Rule-based Evaluation. An emergency incident can be characterized by its severity (e.g., high or low) based on fall estimation and more precisely if

high or low visual and motion activity is identified after the fall, respectively. The patient movement ability level can also provide important information regarding the patient's ability to recover from falls. The assessment of heart rate and blood oxygen levels is also very informational; according to studies [40], low oxygen levels and in conjunction to sudden drop of heart rate can indicate a potential unconscious state of human body.
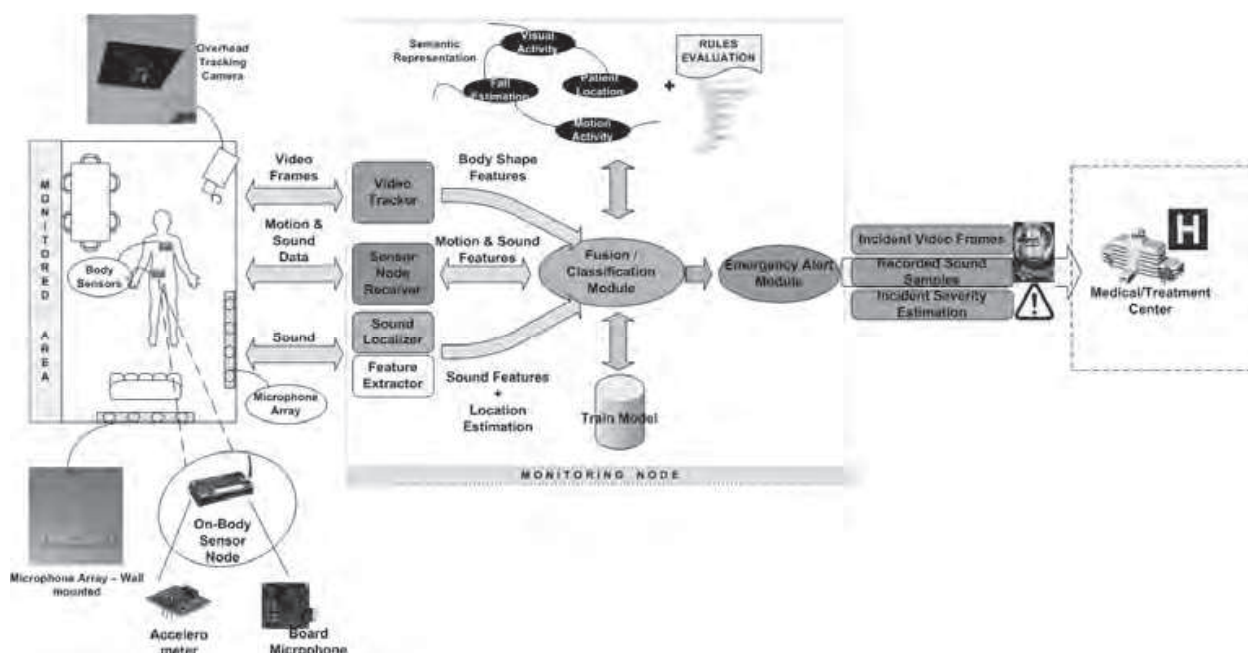

Fig. 4. System Architecture and Data interaction between the movement capturing tools and monitoring node

The aforementioned methods for fall detection concerning the characterization of falls against other movement types (i.e., walking and running) are very promising, especially when compared next to results in related work. Accuracy of 81% fall detection is accomplished using cameras and 91.58% using sound information.

4.2 Complete ambient assisted living

Assisted living facilities provide supervision and assistance with activities of daily living (ADL). In the literature one can find numerous applications and systems dealing with ambient assisted lining environments and homecare monitoring. These applications are trying to monitor, coordinate and differentiate the everyday resident activities by outside healthcare providers and trying to ensure their health, safety, and well being. The continuous monitoring of the elderly's health is a very important issue in view of the fact that the majority of the elderly inhabitants need special care because of chronic diseases and chronic health-related conditions and scheduled office visits are infrequent. Medical services target at a number of medical parameters, which are monitored by specific devices and the measurements are assessed, analyzed and controlled by the specifically designed devices and by the responsible physicians. Arterial blood pressure, heart rate, capillary oxygen saturation, as well as body weight, are some of the most important medical parameters that may be supported in an at-home environment. Homecare patients take advantage from improved health as a result of faster diagnosis and treatment of diseases.

The user's management is strongly bound with the composition and deployment of service personalization [41]. The integrated services involve the user and a service synthesis environment interacting for the production of a personalized service specification. Based on the user, the system maintains a profile that specifies the user information, retrieves personal data from the medical devices and stores the information, monitors the status of the sensors, defines the rules for the medical data and appliances measurements, and executes actions based on the rules defined by the user for each service and the related measurements that were collected.

CAALYX [43] is an EU funded project that aims at increasing older people's autonomy and self-confidence by developing a wearable light device capable of measuring specific vital signs of the elderly, detecting falls and location, and communicating automatically in real time with his/her care provider in case of an emergency, wherever the older person happens to be, at home or outside. The project aims at developing a Wearable Light Device (WLD) to measure specific vital signs of the elderly, detect falls, and communicate automatically in real time via a mobile computer-phone (a Nokia N95 in the current prototype) with his/her caregiver in case of an emergency, wherever the person happens to be, at home or outside. The emergency information includes the geographic position alongside the health information of the elderly to enable the caretaker or emergency service to direct an appropriate response in a timely manner.

One of the recent research projects in assisted living environment is INHOME project [42], which the main goal is to provide the means for improving the quality of life of elderly people at home, by developing generic technologies for managing their domestic ambient environment, comprised of white goods, entertainment equipment and home automation systems with the aim to increase their autonomy and safety. In order to meet an individual's specific needs, a thorough and comprehensive analysis of the user requirements is one of the most important factors to be considered for the design and implementation of a similar project. User choices and preferences are also necessary so as to design interventions at the living environment. In order to define better and arrange the various medical user requirements of the elderly and also incorporate them in the distinguished non-medical requirements, a classification according to the possible most common disease-related profiles of the elderly people has been formulated. The results of the homecare related services could be categorized suitably in a mixture of goals and targets aiming primarily at early detection of a recorded event and intervention, analysis and interpretation of the clinical data, independence from caregivers while receiving healthcare in their own home, independence from physician visits and affordability instead of patients' transport and accommodation.

In order the daily homecare activities to run efficiently, careful planning of the different patients' needs so as to become easier and flexible to continuous changing of scheduling, a complete care solution by STT Condigi [44] is upon an optimum solution. There is a high risk of mistakes in case of bad reporting system, and the patient could not receive what he or she is entitled to. The activity reporting of all visits and current status of the patient is essential and reduces the risk of mistakes and also confirms the actual workload. The platform offers several different functions and products, which the patient can select what he or she actually needs. The platform optimizes the planning of homecare services in a manner that the available staff resources are according to the home visits. The behavior of the patient is recorded in real time and the data are updated so as the homecare services are efficiently comprehended and

reliably performed. There are a range of tools that the patient can use to the activities undertaken, such as an easy-to-use handheld unit for staff with no experience of computers or with limited language skills, mobile phone where the activity reports are transferred directly via the GSM network to the platform, digital pen where nursing staff reports directly in predefined easy to learn forms, and PDA where the whole report is displayed on the screen and is tranferred via GSM directly to the platform. There are also particular alarm systems that are activated for the authorized staff in case of an emergency.
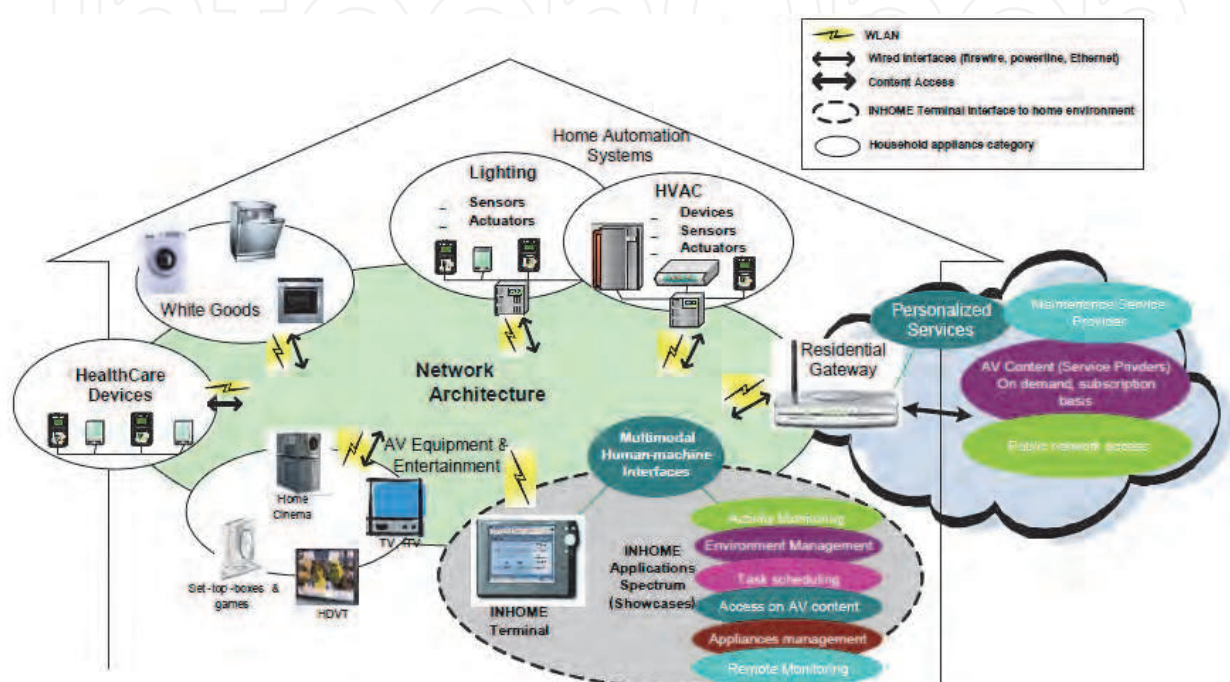
Fig. 5. The INHOME network architecture

4.3 Aging and rehabilitation

We all want the best for our aging parents or grandparents. Fortunately, there are products available that help to ease the concerns of friends and family members of the elderly or infirm aided. Medical alert services are perhaps one of the foremost humanitarian developments of our time. These services can be a saving grace when a patient is not in a frame of mind or physically able to handle a medical emergency. Help can be called for within minutes or even seconds. Experience has shown that the patient feels more confident and less anxious with a medical alert system in place, because friends and loved ones of an elderly or infirm individual can rest easy knowing that there is an extra measure of security.

A nursing home [46] is an alternative way to provide skilled nursing care and rehabilitation services to the people with are chronically ill, injured or with functional disabilities. Most of the applied facilities are applied for the treatment of the elderly people. However, some facilities provide services to younger individuals with special needs, such as developmentally disabled, mentally ill, and those requiring drug and alcohol rehabilitation. Nursing constitutes of independent facilities, however some of those are operated within a hospital or retirement community. Most of the patients and especially elderly people do not want to be in a nursing home or an institute as well as the most relatives of them. But a mixture of circumstances makes institutionalizing a necessity and not a choice.

A variety of different aids for dispersed alarms in home environment are available depending of the safety solution and requirement procedure [47]. The alarm equipment can be classified in two significant categories: the manual alarm equipment and the equipment for automatic alarms. Depending on the patient's situation and the monitoring capability, the suitably alarm equipment can be selected. Most of the alarm equipment is wireless and easy to install sensors. In the case of manual equipment, the alarm transmitters can specify or not the position of the patient, for patients with weak finger or who are permanently confined in bed there are wireless drawstring with and without shut-off, and there also alarm transmitter with fall sensors in case the person is an horizontal position for a pre-programmed period of time. In the special cases for people who have motor disabilities, there exist customized transmitters, which are comprised of pressure, finger and cheek contact, as well as breath-activated sensors, sound-activated alarm and light pressure holder.

An interesting task for homecare monitoring concerns the evaluation of the eNeighbor resident monitoring system [48]. This system can prevent the serious complications that often result from elderly people who experience incidents, such as falls, to receive assistance in a timely manner. This case study examined how the resulting savings in hospitalization and skilled nursing home costs can enable the technology to initially pay for itself in less than one year – and, in subsequent years, potentially in less than six months, by using this system. The time to detect the need for assistance is a major factor in the seriousness of the incident. Risk of falling is an important issue between both older adults in the community and those residing in long-term care facilities. When an elderly person falls in their home and cannot get to a telephone, he or she is dependent upon being found by someone who visits them regularly. These visitors can help detect problems and perhaps reduce the severity of an incident if the person is found in a timely manner. This valuable response time to an incident is critical for preventing complications, and the remote monitoring system tends to be beneficial. The eNeighbor remote monitoring system uses a series of small, unobtrusive sensors that work together to monitor a resident's daily routine. Sensors are placed strategically throughout the residence to detect general activity, or "Activities of Daily Living". The system looks for basic activities, such as movement in the living room or bedroom or the opening and closing of the refrigerator or front door, and establishes a normal range for these activities. If a resident were to fall in the shower or wake up one morning and not be able to get out of bed, the system would not see the expected level of daily activity and would trigger a call to a designated list of contacts that could check on the resident.

4.4 Location-based health monitoring

Recent advances in mobile positioning systems and telecommunications are providing the technology needed for the development of location-aware telecare applications. The positioning system is the perfect solution to create a safer environment for people at risk of wandering. Both indoor and outdoor positioning systems are available in the market. In an indoor situation, the location system can be incorporated for increasing the context-awareness of the systems and for better efficiency. In an outdoor scenario, it can assist people with cognitive disabilities or people suffering from the Alzheimer disease to locate themselves by pressing a button and expect the arrival of help. Given that GPS is the commonly available outdoor location system, and do not function properly indoor, the

development of an indoor location-based health monitoring system is among the most encouraging and beneficial procedure.

In case of nurse houses, the positioning system helps the staff to locate a wanderer either inside or outside the care home. The position givers consist of wireless equipment, such as door opening sensors and indoor or outdoor loop antennas. Wireless positioning givers offer a fairly accurate localization of the patient. In addition to the location, the staff members have also the ability to receive an ID of the wanderer. A mini alarm positional transmitter store the last registered location, that is the signal picked up from the positioning givers, and sends the information wirelessly to the management central station. The staff members can receive the alarm on any displays (screen, DECT phones, pagers). An alarm is automatically sent when the resident enters an unauthorized area. The resident can also activate the alarm manually by pressing the button on the alarm positional transmitter. In both cases, the transmitter sends the last position/location registered to the central station. The system can be customized according to the resident and the authorized and unauthorized areas have to be defined for each resident. The positioning system increases the security for the resident. The positioning components give a real peace of mind not only to the caregivers and residents but also to the relatives.

An additional location-based system for emergency purposes is the EmerLoc [49]. The authors used existing technologies of wireless networks (Bluetooth, WLAN/802.11, GPRS), location-based services (Nibble, GPS), middleware and network application standards (HTTP, OSA/Parlay, WAP, RMI, Jini), in order to assemble an integrated system. EmerLoc incorporates patient-carried equipment comprised of wireless sensors and his/her portable device that continuously monitors the user's biosignals, a micro-computing unit, which is responsible for processing sensor readings and a central monitoring unit (CMU), which transmits the information to the medical personnel. The primary configuration of the system is depicted in Fig. 6 comprising our architecture are the patient and his portable equipment, the attending doctor and his portable equipment and the controlling infrastructure hosted in a hospital or independent telemonitoring service organization. The patient's device (PD) communicates with the CMU to relay critical biosignal and report its present location. Thus, a crisis situation is detected by the PD and communicated to the CMU. Since the CMU is completely aware of the present context of the patient (i.e., physical status and location), it is capable of alerting the attending doctor (or any doctor in proximity to the patient) on the situation and advice him to handle the incident. This platform is making use of heterogeneous network infrastructures (e.g., WLAN, PAN, GSM/UMTS) and the exploitation of the position fixing technologies that such networks offer. In case of an emergency, the transmitted messages contain an overall estimation of the patient's status determined by the deviated biosignals (e.g., serious, very serious), the justification for the estimation and the most recent biosignal readings acquired by the sensors. The CMU has a module of patient's record archive that contains all the medical records of the monitored patients and a module of location-based services (LBS) middleware and provisioning platform handling all different kinds of positioning technologies, i.e. terrestrial position fixing in GSM/UMTS networks, WLAN positioning in 802.11 networks and GPS-based location estimation. A routing algorithm is implemented so as to navigate the doctor via the shortest path to the emergency situation, both in indoor and outdoor scenarios.

In [50] the authors have developed an intelligent, multimodal tracking and observation solution for Assisted Living Facilities (ALFs) incorporating RFID technology and make use of video analysis algorithms for patient tracking and monitoring. The healthcare environment for the elder people consists of a wireless wearable unit along with an attached

RFID tag for the transmission of the patient's vital data and location, wireless transceivers located in the facility communicating with the RFID tags and the wearable unit in order to track and locate the patients, video cameras, which continuously monitor the patients and alarm the staff when an emergency may occur, a PC for video recording and a PDA carried by the staff for receiving alarms, video clips, and vital signs of the patient. The location of the patient can be determined by the relative signal strength of the RF signal received by the RFID tag along with the visual contact of the patient provided by the video cameras. If an emergency situation has arrived from the video analysis, for instance the patient has left the authorized area or the patient lies on the floor for an extended period of time, an alert will arise and the associated video clips will be transferred to the related staff, so as to execute proper commands.
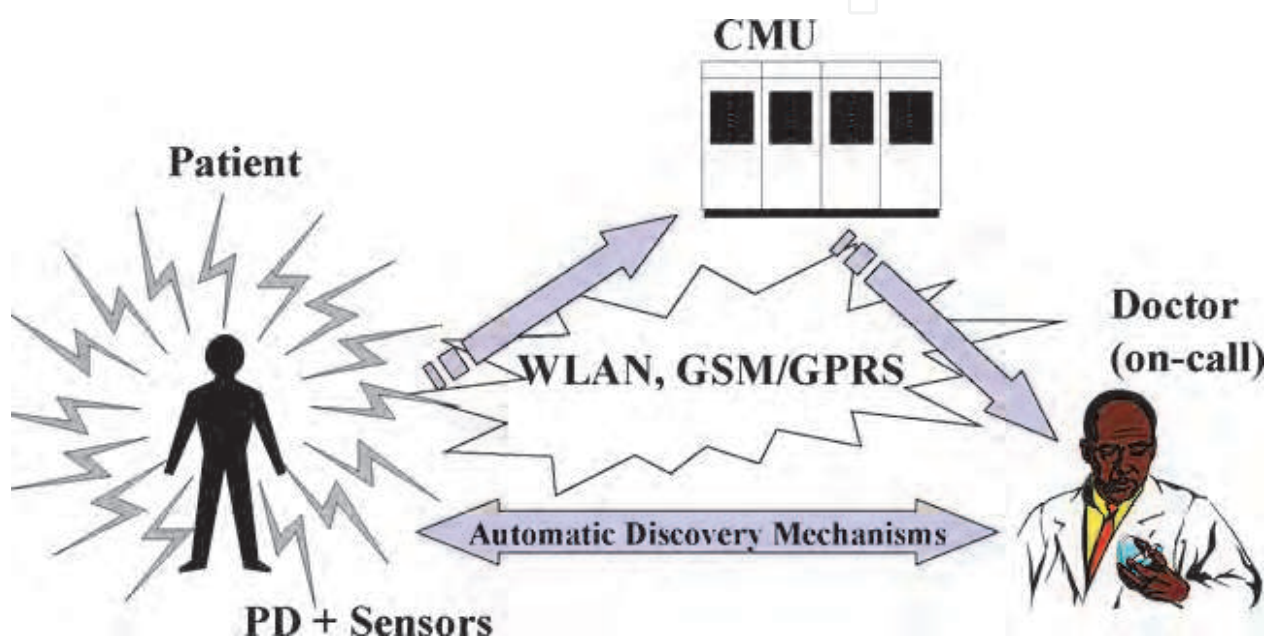

Fig. 6. EmerLoc overall system architecture

4.5 Continuous homecare monitoring

The medical status in homecare of the patients is extensively studied and in the market there a numerous of different pervasive healthcare systems depending on the monitored vital signals. Mobile and wireless concepts in healthcare (e.g., wireless and mobile networks, wireless sensors) are typically related to homecare monitoring. Homecare monitoring using mobile networks includes physiological monitoring of parameters such as heart rate, electrocardiogram (ECG), electroencephalogram, (EEG) monitoring, blood pressure, blood oximetry, and other physiological signals, physical activity monitoring of parameters such as movement, gastrointestinal telemetry fall detection, and location tracking. Using mobile technology, patient records can be accessed by healthcare professionals from any given location by connection to the institution's internal network. Physicians now have ubiquitous access to patient history, laboratory results, pharmaceutical data, insurance information, and medical resources. Handheld devices can also be used in home healthcare, for example, to fight diabetes through effective monitoring.

ZyXEL [51] introduces the Smart Home Gateway (SHG) for health monitoring applications, which is a rugged, pocket-sized, battery powered wireless router. In addition to providing

wireless Internet connectivity through fixed broadband (ADSL/Cable) and 3G/4G broadband, it also enables multiple applications including state-of-the-art, real-time health monitoring through home networks. Via one of its two USB ports, it can connect to IEEE11073 USB, Bluetooth and Zigbee-compliant medical sensors to send real-time data from heath monitoring devices or smart home sensors such as blood sugar or heart rate readings to remote healthcare providers. Health care providers are under regulatory pressure to reduce costs through early detection and prevention and millions of baby boomers are entering the phase that requires greater healthcare support. This has opened up market potential and new revenue opportunities and solutions providers who can use the SHG to offer remote health monitoring services to healthcare providers. Health monitoring services are grouped into three main types – vital sign monitoring like blood pressure etc., disease management like diabetes and hypertension and aging independently that includes bed pressure and other emergency sensors.

A platform that integrates wireless and cellular technologies along with web-based applications is MedApps Remote Health Monitoring Solution [52]. It provides professional care to chronic disease patients in their own residence, by means of sending valuable and timely biometric data to the therapists. This ability can help to improve patient compliance and stabilize patient's conditions, which in turn drives down related care costs. Some of the biosignals that the system use are glucose meters, blood pressure monitors, scales and pulse oximeters. This platform transmits readings from retail health monitors to Electronic Health Records automatically and can be effectively associate patients with chronic conditions with their care providers and family. A remote unit called HealthPAL uses a combination of embedded cellular and bluetooth technologies to automatically transmit readings from compatible monitors to a secure central server. The readings of this unit can be tracked by individuals through an electronic health record (EHR) or an online medical records service, such as Microsoft HealthVault or Google Health. Consequently, healthcare providers can review patient data via enterprise level EHR or by accessing MedApps' full-featured, web-based patient management portal for care professionals.

Another major issue of home monitoring is about the babies. Intelligent Clothing [53] was founded ten years ago to pursue an idea that ordinary washable undergarments could provide an intensive care standard of wireless healthcare monitoring. Continuous evolution of both the industry and the research has produced a manufacturable SmartPatch™ with internet connectivity, suitable for Special Care Baby Units and the home. It is small and least invasive ambulatory monitoring system that weights approximately 9 grams, continuously monitors the heart, respiration and temperature and radios the data to a Bedside Display Unit for onward transmission to doctors via the company's web server. SmartPatch™ enhances collision avoidance integrity suitable for both the home and hospital environment. Each SmartPatch™ will run for 24 hours continuously, on a small inductively rechargeable cell battery. The product is developed for Special Care Baby Units, birthing hospitals, for doctors to monitor their home-based patients remotely and to improve the cost-efficiency of multi-centre clinical trials. The Internet connectivity software monitors respiratory, pulmonary, oximetry and temperature waveforms in real-time. Intelligent Clothing's wireless technology uses ultra low power low frequency radio, an order of magnitude lower than Bluetooth or mobile phone frequencies. Flashing lights in the teddy bear's eyes advice the user that the system is working and, during the recharge cycle, which the battery is fully charged. Data is transmitted to a nearby Bedside Display Unit for onward transmission via

802.11b to a Nurse's Central Station computer in the hospital region or in the home environment via wireless broadband access point.

5. Conclusions and future trends

In this chapter book we analyzed the impact of wireless technology networks and sensors in the homecare environments. Wireless technologies can serve as a new generation technology for mobile health systems providing immediate and ubiquitous health care in a range of different circumstances, as it may handle a variety of homecare needs. We illustrated the different wireless sensor standards that they are making use of, showing their corresponding energy consumption in terms of the biosignals' data rate. Moreover, the measurement range of the sensors is depicted along with the power supply requirements, calibration parameters, output interfaces, and data rates. Signal processing mechanisms are crucial for the extraction of valuable information from the captured biosignals and are closely coupled with the energy consumption. By virtue of that rationale, the taxonomy of approaches to energy saving in sensor networks is also depicted.

We described a number of different systems and case studies of the existing pervasive homecare systems, showing great performance and the biosensors that will mark swift growth in the future and will become integral part of our life. There are appliances easy in their use, precious and very important for the patient, contributing to the improvement and in the prevention of the patient's health. We have provided the confrontations to overcome in different healthcare circumstances, like fall detection, complete ambient assisted living, aging and rehabilitation, location-based health monitoring, and continuous homecare monitoring.

The use of new technologies for the applications of the homecare system appears today as an essential solution. The wireless sensor devices and wireless network systems have become a standardized infrastructure for access in the complex applications for the provision of pervasive homecare for the elderly, chronically ill and children. Such standardized platforms of communication guarantee the advantages of possibility of access and utilization both in the customers (patients) and in the suppliers (caregivers). In other words, we can declare that making use of these technologies offer to the patients who typically live at home, high quality and efficient health services, outweighing the provisional cost and energy consumption.

There are still a few obstacles and open issues in the wireless sensor networks that should be stated and the healthcare research community ought to take into consideration. Selected obstacles can be summarized at the reliability of short-range communication, the changes of policy and organizational flaw to regulate payments and reimbursements of physicians for monitoring or/and consultation, the insufficient battery life, the sensitivity to sensor placements, lack of seamless integration with infrastructure network, privacy and security considerations along with standardization and interoperability. In particular, certain challenges have to be declared and further studied so as the wireless sensor networks to play an important role in enabling ubiquitous communications. The aforementioned challenges can be categorized in hardware issues, in all the layers of the TCP/IP model, and in layer-independent challenges.

As far as hardware issues are concerned and despite the major challenge of energy saving, the unobtrusive design, development and integration of the devices carried by the patients is the main concern since inhabitants must not appear in poor health. The size, form factor,

and physical compatibility to human tissues are crucial, while the sensitivity and the calibration of the sensors transmitting vital signals, particularly in harsh environments, is an additional research challenge, in combination with the real-time data acquisition effectiveness.

With reference to the physical, MAC and network layer, the transmission and routing of the signals is of prior importance. The miniaturization of the devices due to low power energy and small antennas causes higher transmission errors, low bandwidth efficiency and mutual interference when operating in the unlicensed Industrial, Scientific and Medical (ISM) band, allowing the interoperability of the sensors and the systems. Insignificant latency and delay, as well as high Quality of Service (QoS) requirements when vital real-time data are transmitted, are the key issues to provide efficient and best possible delivery of the signal in a fair manner, especially under emergency conditions. Power management and context-aware network configuration of the networks need to be revisited as well. In addition, dynamic management of resources including sensor functionalities is also essential to be compromised. Transport layer should be reliable for medical data delivery ensuring adequate congestion and flow control mechanisms, while application layer is responsible to organize, store and forward medical data securely, intelligently and in a user-friendly context-aware approach, as already discussed in this study.

Different levels of security should be identified, and appropriate mechanisms shall be developed to distinguish life-threatening requests from other applications with various security priorities and appropriate privacy protection measures. The privacy sector requires successful and efficient authentication techniques in wireless sensor networks. Multimodal authentication schemes based on human faces, hand features, and biosignals are actively being developed in both academia and industry. Complex but distinguishable human body characteristics provide an ideal way of authenticating users, but they also create other challenges in protecting their privacy. Software as a service method could be exploited for increasing the scalability and improvement of software deployment.

The technologies of today are tools for a high-quality coordination procedure. Their capabilities are improving rapidly from time to time and their cost decreases exponentially with their use. What is needed is coordination of relevant concepts, attitudes and best practices, so that we can seize the great opportunities that they provide.
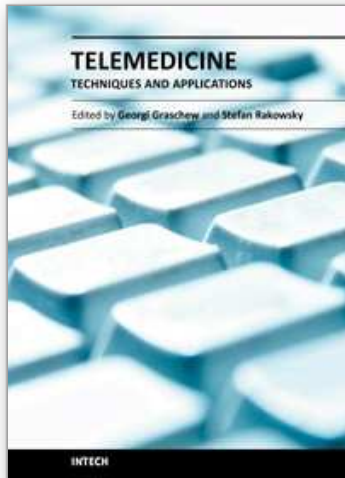
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Telemedicine Techniques and Applications

Edited by Prof. Georgi Graschew

Telemedicine is a rapidly evolving field as new technologies are implemented for example for the development of wireless sensors, quality data transmission. Using the Internet applications such as counseling, clinical consultation support and home care monitoring and management are more and more realized, which improves access to high level medical care in underserved areas. The 23 chapters of this book present manifold examples of telemedicine treating both theoretical and practical foundations and application scenarios.

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