Wireless Sensor Networks in Ambient Intelligence

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Abstract

The Wireless Sensor Networks (WSN) is a necessary technology for the development of the concept of Ambient Intelligence where users are provided of services depending on their context. The WSNs provide the dynamic and flexible structure for the transmission of data acquired from the environment by the sensors. This data is the base for the development of ambient intelligent services adapted with the information acquired from the sensors. In addition, the same WSN makes possible the communication with actuators with possibilities of performing physical changes in the environment.

Keywords

Wireless Sensor Networks, Wireless Body Area Networks, Zigbee, Ambient Intelligence.

1. Introduction

The concept of Ambient Intelligence (AmI) is the new paradigm for providing future applications in the Information Society, hiding the complexity of the technology, offering the intelligent services depending on the context of the user and through natural interfaces. For the development of this concept it is necessary to gather information about the user and the environment in order to be able of knowing the context of the mentioned user. The WSN addresses this necessity providing a wireless and flexible structure for the transmission of the data acquired by sensors to a system in charge of processing this information. In addition, it is also possible to use these type of networks to communicate with actuators that make actions in the environment of the user.

2. Features of Wireless Sensor Networks

The principal feature of a WSN is to transmit wirelessly the data, acquired by sensors in different environments, to the elements (in the same network or in other) in charge of processing this information.

Usually these networks are composed by a great number of nodes. This means that some characteristics as small size, low power consumption, low complexity and low cost are desirable goals when designing a WSN.

Using a system that needs the batteries to be charged every day can become a quite annoying task if the number of devices is quite high. In addition if each device in the system is complex as much to design as to manufacture, this system is not going to be cost-effective to the market. For this reasons users expect batteries to last months to years, and designers expect a simple technology which implies quick and simple designs in order to get globally standard cheap systems.

Every technology, protocol and topology designed for and related to WSN must take into account these characteristics. Protocols must ensure the nodes to realize simple tasks in order to simplify their functionality and they must ensure too that the transmitters and receivers works the minimum possible time in order to reduce power consumption and increase in this way the battery life, and, of course, everything must be done at a price that allows an affordable cost for a network that integrates a high density of nodes.

A. Topologies

In the wide range of scenarios for WSN, it is impossible that one network topology could resolve optimally all the requirements, so there are different topologies [1, 2] for different scenarios. Two are the main topologies used in WSN:

- Start Network
- Mesh Network

The star topology is useful in WSN, especially in the development of Wireless Body Area Networks, WBAN. In this topology, a central node has the responsibility of the coordination with the medical sensors and the communication outside the BAN.

The current developments in WSN are also focused on mesh network topology because it allows for the communication between devices without a central node for routing using a mesh of nodes. This feature eliminates the central failure, and provides self-healing and self-organization. The self organization provides more robustness than a static topology, and allows having mobile devices. For providing this functionality, the current research is working in new algorithms and optimizing algorithms, for self-routing and giving intelligence to the nodes.

Star network: in this case the network is formed by a central element, in charge of controlling the network, which receives the information from wireless sensor end-point nodes. These are physically similar to the mesh network nodes. The end-point nodes send data directly to the central coordinator. From there, data is relayed to other systems. Star networks offer the fastest data gathering speed. The star network topology is typically used in Body Area Networks (BAN), also called Body Sensor Network (BSN) [3], where sensors are located on the body of a person.

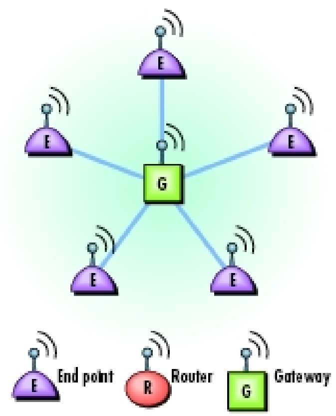


Figure 1. Start WSN topology

Mesh network: it is formed of several modules, usually consisting of a battery, RF adapter, microcontroller, and sensor board, although not all the nodes include sensors. Each wireless node acts as a router, sending and receiving data from other sensors or the gateway. Self-organizing networks automatically determine the best path for data to take from sensor to gateway. Data is automatically sent around failed sensor routers. Because of the limitations, due to battery life, nodes are built with power conservation in mind, and generally spend large amounts of time in a low-power "sleep" mode or processing the sensor data. This topology is used when the sensors are located in a wide area.

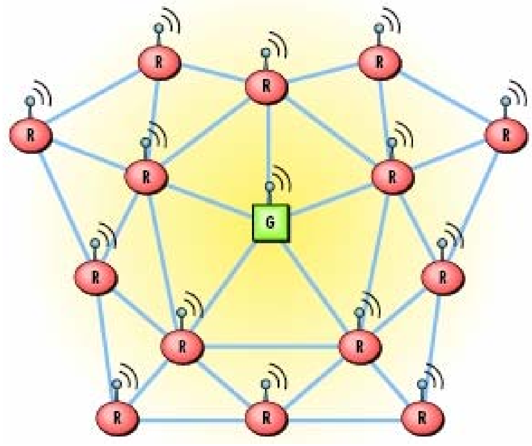


Figure 2. Mesh WSN topology

In both cases, it is usual to have a gateway to communicate with other local or wide area networks. In the case of a mesh network this task can be performed by one or several of the nodes which would have additional electronics and, in the case of the star network, the network coordinator is in charge of this task.

B. Wireless Technologies & Protocols

The development and standardization of new low power consumption and short range wireless technologies have enabled the wireless sensor network concept. Today, there are several options for the development of WSN. These technologies specify the Physical and MAC levels (ex., IEEE 802.15.4), the Network levels (ex., Zigbee) or the three levels in the same specification (ex., Bluetooth). There is also one special Operative System developed to run in the nodes of a Wireless Sensor Network, this Operative System is called TinyOS [4].

802.15.4

The scope of IEEE 802.15.4 task group [5, 6], as defined in its original Project Authorization Request, is "to define the PHY and MAC specifications for low data rate wireless connectivity with fixed, portable and moving devices with no battery or very limited battery consumption requirements". Furthermore, the purpose of the specification is "to provide a standard for ultra low complexity, ultra low cost, ultra low power consumption and low data rate wireless connectivity among inexpensive devices". The characteristics of 802.15.4 make this technology one of most interesting for the development of BAN [7].

IEEE 802.15.4 is specified to work in three different sub-bands of the ISM band (2.4 GHz, 915 MHz in USA and 868 MHz in Europe), with throughputs of 250 kbps, 40 kbps and 20 kpbs respectively. Although the higher frequency makes that for a power transmission given, the range is shorter, this is one of the unlicensed band, more expanded in the world.

Channel access is contention based, via a carrier sense multiple access mechanism with collision avoidance (CSMA-CA). A “battery life extension” mode is also available the period of transmission to a fixed time of approximately 2 ms.

IEEE 802.15.4 specifies the physical layer and portions of the data link layer (DLL). The higher-layer protocols are left to industry (Zigbee) and the individual applications.

Table 1. IEEE 802.15.4 in the ISO-OSI layered network model

<table>
<tr><th>ISO-OSI Model</th><th colspan="2">IEEE 802 Model</th></tr>
<tr><td>7. Application</td><td colspan="2" rowspan="5">Higher layers</td></tr>
<tr><td>6. Presentation</td></tr>
<tr><td>5. Session</td></tr>
<tr><td>4. Transport</td></tr>
<tr><td>3. Network</td></tr>
<tr><td rowspan="3">2. Data link</td><td>IEEE 802.2 LLC, type I</td><td rowspan="2">Other LLC</td></tr>
<tr><td>SSCS</td></tr>
<tr><td colspan="2">IEEE 802.15.4 (MAC)</td></tr>
<tr><td>1. Physical</td><td>IEEE 802.15.4 868/915 MHz (PHY)</td><td>IEEE 802.15.4 2.4 GHz (PHY)</td></tr>
</table>

Zigbee

The Zigbee Alliance [8] is an Industrial Consortium of chip manufacturers, OEM manufactures, service providers, and users in the wireless sensor network market. This Consortium is carrying out the task of association of specifying higher-layer standards, based on IEEE 802.15.4. This includes network, security, and application protocols.

The Zigbee standard specifies both mesh and star network topologies. There are two physical device types for the lowest system cost to allow vendors to supply the lowest possible cost devices: full function devices and reduced function devices.

- Full function device (FFD):
  - Can function in any topology.
  - Capable of being the Network coordinator.
  - Can talk to any other device.
- Reduced function device (RFD).
  - Limited to star topology.
  - Cannot become a network coordinator.
  - Talks only to a network coordinator.
  - Very simple implementation.

Zigbee is an incipient standard that covers the necessities of the network layer in the wireless sensor networks, supported by important companies like Philips, Samsung, Motorola, Mitsubishi Electric, Cisco Systems, Epson, etc.

Bluetooth

Bluetooth (BT) [9] is a radio wave based technology for short-range wireless connectivity among portable and/or fixed electronic devices, such as cellular phones, headsets, personal digital assistants and laptops, as well as for their connectivity to the Internet. The BT specification consists of the core and the profile part: the core part defines how the BT technology works and the profile part describes how the BT technology is used in specific scenarios and use cases. The standard specifies from the physical to the application layer.

Radio frequency operation is in the unlicensed Industrial, Scientific and Medical (ISM) band at 2.4 to 2.48 GHz, using a spread spectrum, frequency hopping, full-duplex signal at up to 1600 hops/sec. The signal hops among 79 frequencies at 1 MHz intervals, to give a high degree of interference immunity. RF output is specified for three different types:

- 0 dBm (1 mW) for a communication range of less than 5 m.
- 4 dBm (2.5 mW) for a communication range of 10-20 m.
- +20 dBm (100 mW) for a communication range of around 100 m.

The Bluetooth 1.1 specification defines a low-power radio link capable of voice or data transmission to a maximum capacity of 720 kbps per channel.

The IEEE 802.15.1 Group Task [10] provided a standard adaptation of the Bluetooth Specification v1.1 Foundation MAC (L2CAP, LMP, and Baseband) and PHY (Radio).

The use of Bluetooth, although more extended that Zigbee is more focused on the personal communications and essential problems, like the power consumption or the synchronization in the BAN, could not be managed with this technology.

UltraWideBand

Ultra-Wideband (UWB) technology has the objective of providing the convenience and mobility of wireless communications, to high-speed interconnect devices throughout the digital home and office. Designed for short-range, wireless personal area networks (WPANs), UWB wants to become the leading technology for freeing people from wires, enabling wireless connection of multiple devices for transmission of video, audio and other high-bandwidth data.

UWB, short-range radio technology, complements other longer range radio technologies, such as WiFi, Wi-Max, and cellular wide area communications. It is used to relay data from a host device to other devices in the immediate area (up to 10 meters).

A traditional UWB transmitter works by sending billions of pulses across a very wide spectrum of frequencies, several GHz in bandwidth. The corresponding receiver then translates the pulses into data by listening for a familiar pulse sequence, sent by the transmitter. Specifically, UWB is defined as any radio technology having a spectrum that occupies a bandwidth greater than 20 percent of the centre frequency, or a bandwidth of at least 500 MHz.

Modern UWB systems use other modulation techniques, such as Orthogonal Frequency Division Multiplexing [11] (OFDM), to occupy these extremely wide bandwidths. In addition, the use of multiple bands in combination with OFDM modulation, can provide significant advantages to traditional UWB systems.

UWB's combination of broader spectrum and lower power improves speed and reduces interference with other wireless spectra. In the United States, the Federal Communications Commission (FCC) has mandated that UWB radio transmissions can legally operate in the range from 3.1 GHz up to 10.6 GHz, at a limited transmit power of -41dBm/MHz. Consequently, UWB provides dramatic channel capacity at short range, that limits interference.

In June 2003, the MultiBand OFDM Alliance (MBOA) was formed, with many of the most influential players in the consumer electronics, personal computing, home entertainment, semiconductor, and digital imaging market segments. The goal of this organization is to develop the best technical solution for the emerging UWB (IEEE 802.15.3a Task Group [11]) Physical and MAC specification for a diverse set of applications. To date, MBOA has more than 60 participants that support a single technical proposal for UWB.

UWB is a technology in the physical level of the OSI stack. There are protocols as Bluetooth, Zigbee, USB [12] that are studying to include UWB in theirs physical layers.

This new technology is being studied is several projects for the development of WBAN [13, 14, 15].

Table 2. Wireless Technologies for WSN

	Zigbee	Bluetooth	UWB
Range	Up to 100m	Up to 100m	Up to 10m
Throughput	250 kbps	720 kbps	480 Mbps (10 m.) 100 Mbps (3 m.)
Transmission levels	0 dBm	0 dBm, 4 dBm or 20 dBm	-41dBm/MHz
PHY/MAC levels	IEEE 802.15.4	IEEE 802.15.1	IEEE 802.15.3a
Network level definition	Yes (Piconet, Scatternet topologies)	Yes (Mesh, Star topologies)	No
OEM modules in the market	Incipient penetration	High penetration	Low penetration

Software, TinyOS

TinyOS [4] is an open-source operating system, designed for wireless embedded sensor networks. It features a component-based architecture, aimed at enabling rapid innovation and implementation while minimizing code size, as required by the severe memory constraints inherent in sensor networks. TinyOS's component library includes network protocols, distributed services, sensor drivers, and data acquisition tools -all of which can be used as- is or be further refined for a custom application. TinyOS's event-driven execution model enables fine-grained power management, yet allows the scheduling flexibility made necessary by the unpredictable nature of wireless communication and physical world interfaces.

TinyOS has been ported to over a dozen hardware platforms and numerous sensor boards. A wide community uses it in simulation, to develop and test various algorithms and protocols. New releases see over 10,000 downloads. Over 500 research groups and companies are using TinyOS on the Berkeley/Crossbow Motes. Numerous groups are actively contributing code to the sourceforge site and working together to establish standard, interoperable network services, built from a base of direct experience and honed through competitive analysis in an open environment.

3. WSN nodes

The principal device in a WSN is the network node, also called mote. This device, battery powered, has the RF communication for the transmission and the reception of the information, an interface between the module and the sensor and a microcontroller.

Normally this microcontroller is a simple 8-bit microcontroller. Since, as commented above, one of the main goals when designing nodes in WSN is simplicity, this kind of processors must be enough powerful to manage communications, and their low clock frequencies reduce power consumption, thus increasing the battery life.

Depending on the size and shape requirements, batteries will be a key factor in the design of the nodes. Normally batteries are the bottleneck of the design when referring to size. The higher the capacity of the battery is needed the bigger the size is. A trade off between these two parameters must be done. Plenty of commercial batteries are available in the market: Lithium-Ion rechargeable batteries, small coin batteries, high capacity Ni-Cd batteries, etc…

Regarding the transceivers for the RF part of the device, normally similar options are available from different manufacturers. This allows the designers to choose between different prices and characteristics depending on the needs of each design.

In the **tables 4 and 5** a list with the commercial modules available in the market and theirs characteristics **is included**.

Table 4. Commercial Modules for WSN

	iMote2	iMote	MicaZ	TelosB	MICA2DOT (MPR500CA)	Mica2
Description	Intel low power wireless sensor module	Intel low power wireless sensor module	Low Power Wireless Sensor Module	Low Power Wireless Sensor Module with USB	Small Size Low Power Wireless Sensor Module (no 802.15.4)	Low Power Wireless Sensor Module (no 802.15.4)
Operative System	TinyOS	TinyOS	TinyOS	TinyOS	TinyOS	TinyOS
Company	Intel	Intel	Xbox	XBOX	XBOX	XBOX
Data Rate	250Kbps	720kbps	250kbps	250 kbps	FSK data rate up to 76.8 kBaud	FSK data rate up to 76.8 kBaud
RF transceiver	ChipCon CC2420	Bluetooth	CC2420	CC2420	cc1000	cc1000
Frequency	2,4 GHZ	2,4GHz	2,4GHz	2,4 Ghz	868/916MHz, 433MHz or 315MHz multi-channel	868/916MHz, 433MHz or 315MHz multi-channel
Microcontroller	Intel® PXA 271 Xscale®	Atmega128L, 8 MHz	Atmega128L, 8 MHz	TI MSP430	ATmega128L	ATmega128L
Power Requirements	Ultra low voltage at low speeds (0.85V up to 104 MHz) Deep sleep (0.1mW)	Deep sleep 1 uA	8 mA (active); < 15uA (sleep)	1.8 mA (active), 5.1 uA (sleep)	8 mA (active), < 15 uA (sleep)	8 mA (active), < 15 uA (sleep)
Current deployment state	Developed	Developed	Developed	on sale	On sale	On sale

Table 5. Commercial Modules for WSN

	TelosA	tmoteSky	EM250	EM260	CC2430
Description	Low Power Wireless Sensor Module with USB (discontinued), new version called tmoteSky	Low Power Wireless Sensor Module with USB	Chip with ZigBee System-on-Chip (micro and transceiver)	Chip with ZigBee System-on-Chip (micro and transceiver) - EmberZNet Stack (mesh NW included)	Chip with ZigBee System-on-Chip (micro and transceiver) - ZigBee™ protocol stack (Z-Stack™)
Operative System	TinyOS	TinyOS	Custom	Custom	Custom (Airbee)
Company	Moteiv -	Moteiv	Ember	Ember	Chipcon
Data Rate	250kbps	250kbps	250kbps	250kbps	250kbps
RF transceiver	CC2420	CC2420	Custom	Custom	cc2030
Frequency	2,4Ghz	2,4Ghz	2,4Ghz	2.4Ghz	2,4Ghz
MicroControlador	TI MSP430	TI MSP430	embedded 16-bit XAP2 microcontroller	16MHz	8051 8-bit single-cycle microcontroller
Power Requirements	19 mA (active- radio on), 2.4 uA (sleep)	19 mA (active- radio on), 5 uA (sleep)	1uA max (deep sleep), 29mA (RX+CPU)	1uA max (deep sleep), 26mA (RX+CPU)	RX +CPU->27 mA, 0.6 uA sleeping
Current deployment state	Discontinued	on sale	pre-order	pre-order	Pre-order

4. Wireless Sensor Networks Applications

The number of potential applications of sensor network technology is growing all the time. Applications of WSN technology include:

- Remote Control and Monitoring in industrial System
- Home Automation and Security
- Inventory and Logistic
- Natural Environment Monitoring
- Agriculture
- Human Interface Devices
- Military Monitoring
- Health Monitoring [16] (i.e.BAN)
- Etc.

The following table includes a table of Wireless Sensor Networks projects developed in the European Union (Body Area Networks are not included).

Table 3. Mesh Networks projects

Name	Description	Web
WiSeNts	Cooperating Embedded Systems for Exploration and Control featuring Wireless Sensor Networks	www.embedded-wisents.org/
EYES	self-organizing and collaborative energy-efficient sensor networks	www.eyes.eu.org
Hogthrob	Networked on-a-chip nodes for sow monitoring	www.hogthrob.dk
Intairner	Intelligent Air Monitoring Network for monitoring the quality of the air.	
LakeNet	Embedded Sensor Network for Environmental Monitoring	www.nd.edu/~lemmon/lakenet-project/lakenet.html
RUNES	Reconfigurable Ubiquitous Networked Embedded Systems	www.ist-runes.org/
SPOT	techniques for secure localization of wireless devices in sensor networks	http://imm.dtu.dk/sens/secloc.html
DTS/SN	Delay Tolerant Networks / Sensor Networks	http://www.sics.se/cna/dtnsn/index.html
ADA	Advanced Distributed Network for Telemonitoring Services, Air Quality Monitoring	www.ada-ist.org/
Optima	Wireless Sensor Network for the localization of patients in a hospital environment using Bluetooth	
Good Food	WSNs for Food Safety and Quality Monitoring	http://ami.goodfood-project.org

Body Area Networks

One special case of WSN is the Body Area Network (BAN). A BAN has compact units which enable transfer vital signs from the body of the user between the user's location and the clinic or the doctor. There are a lot of projects that use BAN for monitoring the state of the patients.

This section gathers some relevant examples of projects related with BAN technologies and a comparison of their characteristics.

Sensation

SENSATION, an European project, researches micro and nano sensor technologies with the goal of monitoring, detecting and predicting the human physiological state in relation to its alertness, fatigue and stress at anytime, in anyplace and for everyone.

Web Site: http://www.sensation-eu.org/index.html

MobiHealth

The MobiHealth European project has developed a customisable monitoring system for vital signals, based on a BAN [17] and an m-health service platform, utilizing UMTS and GPRS networks. The prototype includes Bluetooth for the communication intraBAN and the central device is a PDA.

Web Site: http://www.mobihealth.org/

VitaSens

VitaSens [18] is a wireless Body Area Network, developed by the Fraunhofer Institute for Integrated Circuits in Germany. The BAN developed includes ECG, PSO2, temperature, blood pressure and respiratory sensors. The first prototype has been developed using Bluetooth for the communication between sensors and the central unit, whereas -currently - is being adapted to - Zigbee for this communication.

Web Site: http://www.ban.fraunhofer.de/

Human++

Human++ project of the Interuniversity MicroElectronics Centre of Belgium is developing a WBAN [15]. The objectives of the research includes Micro-Power generation (vibrational and thermal scavenger) for increasing the lifetime of battery-powered devices, 4ltra low-power radios, using UWB (IEEE 802.15.4a), Biosensors (DNA sensors), MEMS, EEG, etc.

Web Site: http://www.imec.be/human/

Ubimon

Ubimon [19] is a research project, aimed at the development of an Ubiquitous Monitoring Environment for Wearable and Implantable Sensors. This project has developed a BSN, including ECG, SPO2, accelerometer, temperature and humidity sensors. In this research, a RF-module has been developed, based on IEEE 802.15.4 technology (CC2420 RF transceiver), the TinyOS and the transceiver CC2420. A Compact Flash-802.15.4 has been developed for PDAs and also software for Data Mining.

Web Site: http://www.doc.ic.ac.uk/vip/ubimon/home/index.html

Codeblue

The University of Harvard in USA is carrying out the Codeblue project [20]. This project is exploring applications of wireless sensor network technology to a range of medical applications, including pre-hospital and in-hospital emergency care, disaster response, and stroke patient rehabilitation, and localization with RF (MoteTrack Project). The main development of this project is a WBAN with battery-powered "motes" and medical sensors (ECG, SPO2, Motion, EMG). The RF technology is based on the 802.15.4 standard, TinyOS and Mica and Telos modules.

Web Site: http://www.eecs.harvard.edu/~mdw/proj/codeblue/

PRIMA: Portable Remote Intelligent Medical Agents

The PRIMA project of the University of Galway in Ireland is focused on the research, design, and evaluation of a prototype intelligent agent based system for portable/remote monitoring and management of at cardiac risk patients. In this project a WBAN, with an ECG smart sensor, Neural Networks, and RF localization using Bluetooth, has been developed. At the end of the PRIMA project, a spin-off called Syncrophi has started the project BIOSENSE . In this project a WBAN using Zigbee will be developed.

Web Site: http://ecrg.it.nuigalway.ie/projects/prima.html

WBAN-ETH

This project, of the Swiss Federal Institute of Technology of Zurich, is developing a Wireless Body Area Network [14] of non-invasive sensors with energy efficiency, unobtrusiveness, scalability and cost structure. The RF technology is Ultra Wide Band, from 3 to 6 GHz, and the current work is focused on the effects of body blocking with UWB. The objective of the project is to support a high density of heterogeneous nodes (about 50 per body).

Web Site: http://www.nari.ee.ethz.ch/wireless/research/projects/ban.html

Basuma: Body Area System for Ubiquitous Multimedia Applications

This project is funded by the German Government, with the collaboration of universities and Philips Research. They are developing a wireless BAN that allows for monitoring heart rate, blood pressure, etc. The BAN should be able to make intelligent decisions about the state of health and send the information to the medical services. It is mainly based upon UWB technology.

Web Site: http://www.basuma.de

MOTETRACK

This project has been developed in the University of Harvard (USA). In this project has been developed a RF-based location tracking system. It is based on low-power radio transceivers coupled with a modest amount of computation and storage capabilities, such as the Berkeley Mica2 sensor "mote." The source code for the modules is available on the web.

Web Site: http://www.eecs.harvard.edu/~konrad/projects/motetrack/

WBAN-Alabama

A research group in the University of Alabama in Huntsville, USA, has developed a wireless BAN of intelligent motion sensors for computer assisted physical rehabilitation, using 802.15.4 modules, Telos, and TinyOS. This group has also developed WBANs, with ECG, SPO2 and breathing sensors.

Web Site: http://www.ece.uah.edu/~jovanov/

Healthy-Aims

Healthy Aims is an IP project, aimed at the development of intelligent medical implants sensors, functional electrical stimulation, human body motion sensors, etc. In this project a body area network has been developed, enabling communication from implants on the body devices to a base unit, which may be up to 3 m. away, using implantable power sources, biomaterials and RF technologies for implantable devices.

Web Site: http://www.healthyaims.org/

MyHeart

The European IP project MyHeart is developing a Body Area Network using smart-clothes. It includes electronic systems and sensors embedded into functional clothes. Intelligent clothes are able to continuously monitor the vital signs of the citizen, to make diagnosis and trend detection and react on it. Intelligent clothes have as integrated wireless technology, Bluetooth, to link to user devices.

Web Site: http://www.hitech-projects.com/euprojects/myheart/

The following pages include two summary tables (6 and 7) with the main technical characteristics of the BAN projects mentioned.

Table 6. Body Area Networks Projects

	WBAN-ETH	MobiHealth	PRIMA	WBAN-Alabama	My Heart	Ubimon	Basuma	Sensation
Description	WBAN of non-invasive sensors The RF technology is UWB	customisable BAN with Bluetooth and GPRS/UMTS	WBAN for portable/remote monitoring and management of at cardiac risk patients (ECG, localization)	WBAN of intelligent motion sensors for computer assisted physical rehabilitation	BAN of intelligent sensors using smart-clothes	Ubiquitous Monitoring Environment for Wearable and Implantable Sensors	"Body Area System" for "Ubiquitous Multimedia Applications".	
Network technology/ Protocols	UWB	Bluetooth	IEEE 802.15.4	IEEE 802.15.4	wired BAN, BAN->PDA (Bluetooth), PDA->Server(Internet)	802.15.4	UWB-Frontend and 802.15.3 (High Rate Wireless PAN) for MAC	
Network and Sensor Data Rate	NA	115 Kbps	250kbps	250kbps	56 kbaudps	250 kbps	20 Mbps	
Synchronization	NA	NA	NA	NA	Hardware	NA	NA	
RF transceiver	NA	Mobi Bluetooth RC, and Bluetooth of mobiles and Iraq (coordinator)	NA	CC2420 RF transceiver	NA	CC2420 RF transceiver	NA	
Microcontroller & OS	NA	NA	NA	Telos (MSP430)-TinyOS	NA	TI MSP430 ultra low power processor - TinyOS	Leon2	
Frequency	3Ghz - 6Ghz	2,4Ghz	2,4 GHz	2.4 GHz	2.4 GHz (LAN)	2,4 GHz	UWB	

	WBAN-ETH	**MobiHealth**	**PRIMA**	**WBAN-Alabama**	**My Heart**	**Ubimon**	**Basuma**	**Sensation**
Power Requirements	NA	NA	NA	NA	NA	Active Mode: 280uA at 1MHz 2.2V , Standby Mode: 1.6uA , Off Mode: 0.1uA	NA	
Batteries	NA	NA	NA	2 AA batteries	Ion-Lithium Battery	NA	NA	
Battery-life time	NA	less than 2 hours	NA	NA	2 hours	Low current consumption (RX:19.7mA TX:17.4mA)	NA	
LAN/WAN technologies	NA	GPRS/UMTS	NA	GPRS	Bluetooth, GPRS	Wi-Fi, GPRS	NA	
Current deployment state	Current work is focused in the effects of body blocking with UWB (1st publication, 2003)	(2002-2003*)Prototype available- * Delayed	Prima project is closed. The spin-off continues with the R&D		Project: 2004-2007 Prototyping	Prototype available: leads ECG, 2-leads ECG strip, and SpO2---Future: ambient sensors, data mining	2004-2006, Developing	

6. Wireless Sensor Networks and AmI

The Ambient Intelligence paradigm is going to change the way that the information society services are offered to the users. This new paradigm is based on:

- The technology is peripheral and its complexity is hiding, in comparison, for example, with the current access to Internet services where the user is in the periphery and access to the services through computer devices.
- Services have not only to be requested by the user but the intelligence of the system will allow the automatic provision of services depending of the profile and the context of the user.
- The interaction between the services and the final user will be through natural interfaces, adapting to the characteristics of the final user.

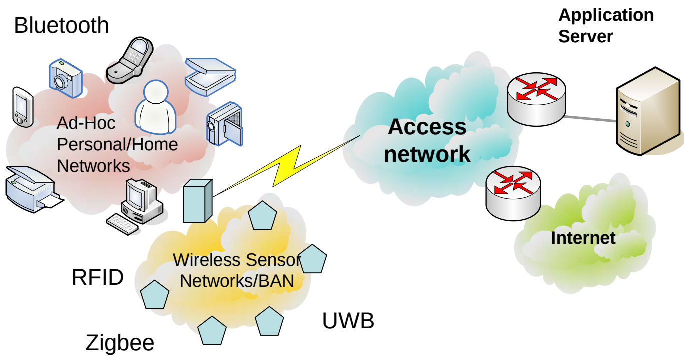
Therefore, in order to achieve services that follow this paradigm, it is necessary:

- To know the context of the user. For this reason, it is obvious the need of sensors in the environment and the body of the person that acquire data dealing with the user's environment and state.
- Distributed intelligence that allows to process the context and user's profile information in order to know the conditions of the user and its environment in real time, used by the AmI services in order to offer the appropriated service through the natural interfaces.
- There is not limit for the AmI services, but in a great number of cases it will be necessary to use actuators that make possible to perform actions in the physical environment of a user (ex., an engine that allows for opening a door).

Therefore, there is a need of transmission of data from sensors to the system elements where the intelligence is. The use of a mesh WSN that allows the transmission of data from sensors to those elements is, therefore, key part of an AmI system [21]. The WSN allows the easy dispersion of sensors in the large environments in order to monitor what happens.

The same can be said about a BAN that allows the monitoring of vital sign parameters of a user.

A combination of both networks is also possible including mobile nodes in the body of a person that can be directly connected with the fixed mesh network in the environment.



Moreover, it is necessary the integration and the interoperability of these networks with the Personal, Local, Metropolitan and Wide are networks used in the "classic" applications.

On another hand, AAL services need to perform actions in the physical environment. The same WSN used in the connection of sensors, allow the transmission of commands and data to actuators in the environment (engines, lights, etc.) and user body (vibrator, leds, etc.)

7. Conclusions

The development of new technologies such as wireless technologies, mobile devices and embedded software is opening the doors to new applications with the development of Wireless Sensor Networks within AmI paradigm. The WSN could collect data from the environment and this data could be used for the development of intelligent systems adapted automatically to the context, within the paradigm of the Ambient Intelligence. The enormous potential of wireless sensor networks opens the door to entirely new applications.

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