Wireless body area networks: status and opportunities

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Abstract

Future Internet and Internet of Things are hot research topics mainly due to 2 enabling factors: the increasing use of wireless networks and the constant miniaturization of electrical devices. Both enablers have also empowered the development of Wireless Body Area Networks (WBANs). In these networks various sensors are attached on clothing or on the body or even implanted under the skin. The wireless nature of the network and the wide variety of sensors offer numerous new, practical and innovative applications to improve health care and the Quality of Life. The sensors of a WBAN measure for example the heartbeat, the body temperature or record a prolonged electrocardiogram. Using a WBAN, the patient experiences a greater physical mobility and is no longer compelled to stay in the hospital. This paper offers a survey of the concept of Wireless Body Area Networks and presents a unique European initiative which offers access to a federated set of European Testbeds and Research Facilities in the area of Future Internet.

1. Introduction

The aging population in many developed countries and the rising costs of health care have triggered the introduction of novel technology-driven enhancements to current health care practices. For example, recent advances in electronics have enabled the development of small and intelligent (bio-) medical sensors which can be worn on or implanted in the human body. These sensors need to send their data to an external medical server where it can be analyzed and stored. Using a wired connection for this purpose turns out to be too cumbersome and involves a high cost for deployment and maintenance. However, the use of a wireless interface enables an easier application and is more cost efficient [1]. The patient experiences a greater physical mobility and is no longer compelled to stay in a hospital. This process can be considered as the next step in enhancing the personal health care and in coping with the costs of the health care system. Where eHealth is defined as the health care practice supported by electronic processes and communication, the health care is now going a step further by becoming mobile. This is referred to as mHealth [2]. In order to fully exploit the benefits of wireless technologies in telemedicine and mHealth, a new type of wireless network emerges: a wireless on-body network or a Wireless Body Area Network (WBAN). This term was first coined by Van Dam et al. [3] and received the interest of several researchers [4–8].
A Wireless Body Area Network consists of small, intelligent devices attached on or implanted in the body which are capable of establishing a wireless communication link. The increase in applications and interest for such sensors and Body Area Networks can be seen in the growing interest to move to a Future Internet or Internet of Things in which also household equipment, cars, packages, parcels, … carry sensors and communicate with each other and the outer world.

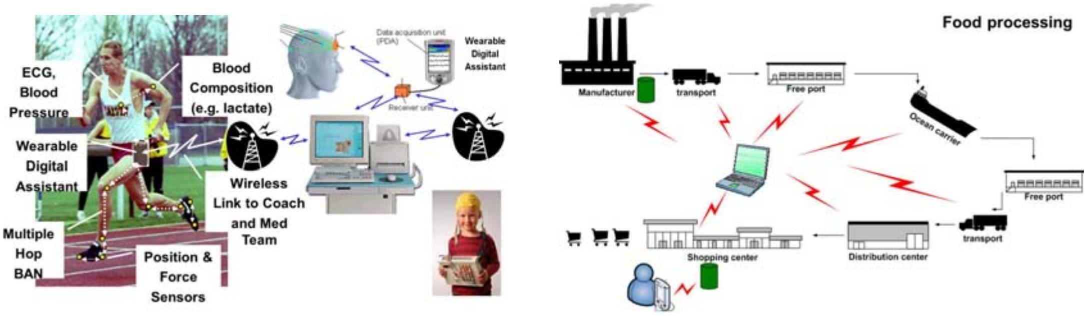

Figure 1: Two examples of the evolution towards the “Internet of Things”

2. Challenges for Wireless Sensor Networks & Body Area Networks

Generally speaking, two types of devices can be distinguished: sensors and actuators. In order to realize communication between these devices, techniques from Wireless Sensor Networks (WSNs) and ad hoc networks could be used. However, because of the typical properties of a WBAN, current protocols designed for these networks are not always well suited to support a WBAN. The following illustrates the differences between a Wireless Sensor Network and a Wireless Body Area Network:

- The devices used have limited energy resources available as they have a very small form factor (often less than 1 cm3 [9]). Furthermore, for most devices it is impossible to recharge or change the batteries although a long lifetime of the device is wanted (up to several years or even decades for implanted devices). Hence, the energy resources and consequently the computational power and available memory of such devices will be limited;
- All devices are equally important and devices are only added when they are needed for an application (i.e. no redundant devices are available);
- Extremely low transmit power per node is needed to minimize interference and to cope with health concerns [10];
- The propagation of the waves takes place in or on a (very) lossy medium, the human body. As a result, the waves are attenuated considerably before they reach the receiver;
- The devices are located on the human body that can be in motion. WBANs should therefore be robust against frequent changes in the network topology;
- The data mostly consists of medical information. Hence, high reliability and low delay is required;
- Stringent security mechanisms are required in order to ensure the strictly private and confidential character of the medical data;
- And finally the devices are often very heterogeneous, may have very different demands or may require different resources of the network in terms of data rates, power consumption and reliability.

3. Research Facilities in the area of Wireless Networks and Future Internet

Experimentally driven research is considered to be a key factor for growing the European Internet industry. In order to enable this type of RTD activities, a number of projects for building a European facility for Future Internet Research and Experimentation (FIRE) have been launched in the past, each targeting a specific community within the Future Internet ecosystem. Through the federation of these infrastructures, innovative experiments become possible that break the boundaries of these domains. Besides, infrastructure developers can utilize common tools of the federation, allowing them to focus on their core testbed activities.

Recent projects have already successfully demonstrated the advantages of federation within a community. Fed4FIRE (a project funded under the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 318389) implements the next step in these activities by successfully federating across the community borders and offering openness for future extensions.

Fed4FIRE is establishing a common federation framework by developing, adapting and adopting tools that support experiment lifecycle management, monitoring and trustworthiness. The project also identified challenges for which novel solutions have to be developed, such as SLA management and testbed reputation, advanced reservations, advanced support for services, handover between the different tools used in the different stages of the experiment lifecycle, and improved user friendliness of experimenter tools. The corresponding developments are currently taking place. A large number of existing experimentation facilities in Europe are being adapted to seamlessly integrate in the federation. Such facilities typically focus on different kinds of networking related research or on different communities regarding services and applications. Example domains are optical networking, wireless networking, software defined networking, cloud computing, grid computing, smart cities, etc.

3. Available testbeds

The Fed4FIRE-project partners offer a number of individual testbeds which can be combined to perform large scale experiments. Of course each testbed is available also as a self-contained environment for dedicated experiments.

In later stages of the project, additional facilities will be included in the offering thus expanding the scale and scope of the opportunities for experiments, but the current testbeds are:

Wired testbeds

- Virtual Wall (iMinds, Belgium)
- PlanetLab Europe (UPMC, France)

Wireless testbeds

- Norbit (NICTA, Australia)
- w-iLab.t (iMinds, Belgium)
- NITOS (UTH, Greece)
- Netmode (NTUA, Greece)
- SmartSantander (UC. Spain)
- FuSeCo (FOKUS, Germany)

OpenFlow testbeds

- UBristol OFELIA island
  (Univ. Bristol, UK)
- i2CAT OFELIA island
  (i2CAT, Spain)
- Koren testbed (NIA, Korea)
- NITOS testbed (see wireless
  testbeds)
  (UTH, Greece)

Figure 2: Overview of the Fed4FIRE Testbeds

Cloud computing testbed

- BonFIRE is a multi-cloud testbed for services experimentation
- EPCC and Inria cloud sites
- iMinds Virtual Wall testbed for emulated networks

5. iLab.t Wireless Lab

When researching or developing products or solutions that will be used over wireless networks, or designing the protocols that drive these wireless networks, experimentation is a crucial aspect in determining the reliability of a solution. Small-scale experiments with a limited number of wireless devices may already be helpful to discover certain functional, stability or performance issues with a solution under test, caused by the unpredictable behavior of the error-prone wireless environment. However, the behavior of the same solution in a larger, more realistic and more complex wireless environment, characterized by a diversity of interfering wireless technologies and devices may be completely different. Furthermore, the repeatability of wireless experiments that are carried out on top of a temporary set-up of wireless devices is limited.
The w-iLab.t testbed provides researchers and developers with the hardware and with software tools to develop and test their wireless solutions (or their solutions that rely on wireless connectivity) in a time-effective way in small and large-scale set-ups. Experimenters are provided with the tools to install and configure firmware and software on (a selection of) wireless nodes, schedule automated experiments, and collect, visualize and process results.

There are 2 parts in this testfacility:

w-iLab.t Office
The w-iLab.t Office consists of a wireless Wi-Fi (IEEE 802.11a/b/g) and sensor network (IEEE 802.15.4) testbed infrastructure, deployed across three 90 m x 18 m floors of the iMinds office building in Ghent, Belgium. At about 200 spots throughout the office spaces, meeting rooms and corridors, wireless hardware is mounted to the ceiling. The lay-out of a single floor of the office testbed is displayed below (each dot represents a hardware spot, the color refers to a "testbed zone").
At each of these spots, following fully configurable hardware is available:

- 1 embedded PC with 2 Wi-Fi a/b/g interfaces
- 1 sensor node (TelosB) with temperature, humidity and light sensors and a IEEE 802.15.4 radio interface
- A custom-designed "environment emulator" board, enabling unique features of the testbed including the triggering of repeatable digital or analog I/O events at the sensor nodes, real-time monitoring of the power consumption, and battery capacity emulation.

Experimenters may use the hardware at all spots or at a subset of these spots, each time enabling either Wi-Fi interfaces, the sensor node, or both devices, to carry out their experiments.

w-iLab.t Zwijnaarde

In Zwijnaarde, Belgium, located approximately 5 km away from the "w-iLab.t Office", a second w-iLab.t deployment is found in an unmanned utility room (size: 66m x 22.5m). As opposed to the Office deployment where people work and where there are also operational wireless networks (WLAN, DECT phones) installed, there is a lot less external radio interference in the Zwijnaarde deployment. At this location, hardware is hosted at another 60 spots. Every spot is equipped with:

- 1 embedded PC with 2 Wi-Fi a/b/g/n interfaces and 1 IEEE 802.15.1 (Bluetooth) interface
- a custom iMinds-Rmoni sensor node with an IEEE 802.15.4 interface
- an “environment emulator” board (see above).

There are two additional possibilities in the Zwijnaarde deployment:

- A number of cognitive radio platforms (including USRPs) as well as specialized spectrum scanning engines are available at this location. This enables state-of-the art research in the field of cognitive radio and cognitive networking.
- Mobile robots allow experiments to be scheduled that include up to 20 mobile nodes to be operated in the environment.

Figure 3: Overview of the w-iLab.t Zwijnaarde unmanned facility (above, circles indicate positions of sensor nodes) with a sample of the available mobile sensornodes mounted on a mobile remote (left)

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