Using of mobile platforms for sensor nodes in Biomedical Wireless Sensor Networks

Georgi Stoyanov [1], Borislav Naidenov [2], Stela Kostadinova [3]

Abstract – **The rapid pace of technological advances in recent years has enabled a significant evolution and deployment of Biomedical Wireless Sensor Networks (BWSN) which have the important impact nowadays. Related technologies have variety of applications, and they are key enabling technologies of IoT (Internet of Things) in the field of e-health. IoT solutions, based on different mobile platforms, offering cost efficiency, flexibility and simplicity of development, can be used in BWSNs as sensor nodes or gateways. The current paper aims to summarize the challenges related with the collection, manipulation and exploitation of the data generated by these networks, using mobile platforms as sensor nodes. The biomedical data security, the type of communication and the sensor node's software, also will be considered in terms of increasing the efficiency of data transmission in BWSNs.**

Keywords – ***Biomedical Wireless Sensor Networks (BWSN), mobile platforms, sensor node.***

I. Introduction

With the swift progress in wireless communication and semiconductor technology, the sensor networks are developing rapidly, covering areas of different applications, including in medicine. Rapidly growing number of various wearable health monitoring devices in recent years is used for a wide range of medical and healthcare solutions. These devices provide continuous and real time health monitoring to patients, users, doctors or medical centers and they are responsible for collecting, processing and transmitting data from a wide range of body-sensors such as: blood pressure, heart rate, respiration rate, electrocardiography (ECG) for the heart health, Electromyography (EMG) for the muscles control, electroencephalography (EEG) for the brain signals, oxygenation signals, and temperature. Some of the latest research in this area are focused on the wireless, mobile, and easy to wear solutions to make this monitoring more user friendly since the wires may limit the user activities and level of comfort and also influence significantly the measured results. Nevertheless, the technology advances in miniaturization and integration of microcontrollers, physical sensors, embedded radio interfaces, wireless networking and microfabrication have enabled a new generation of wireless sensor networks suitable for many biomedical applications [1].

Biomedical Wireless Sensor Networks (BWSN) are a subcategory of wireless sensor networks (WSNs) which operate in a pervasive manner for on body applications, especially for health and medical aims. This network is designed to work independently and to make the link between different medical sensors attached to the body or implanted in it. These sensors have wireless capability with a central sensor, giving it any information on the state of the body. Once receiving the information, they transmit it to a central controller, which processes it and forwards it to an external device, which displays the collected information. Biosensors can be replaced by a variety of devices, called mobile platforms, which can also be used as a central node or gateway of BWSN. Mobile platforms represent development boards, such as raspberry pi, arduino and intel galileo, which can be used for various applications in biomedicine, depending on the software and the necessary configurations [2]. The architecture of BWSN is illustrated in Fig.1.

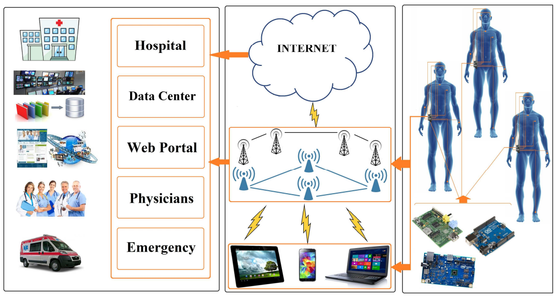

Fig. 1. Architecture of Biomedical Wireless Sensor Network

Actually the biomedical sensor nodes integrated into BWSN, can provide a novel information technology that will be able to support early detection of abnormal conditions and prevention of serious consequences. Today BWSN offer many advantages like the mobility of the users, flexibility and integration. Thus, today's body sensor networks are very useful to offer assistance to the users, patients, and also persons with disabilities. That's why a large number of novel biomedical sensors are proposed by different companies to cover the requirements of a wireless sensors node especially in terms of high accuracy, small scale factor, high integration, multisensory versatility and low-power consumption [3].

The aim of this paper is to consider the different types of biomedical sensors used in BWSN and categorized them according to various addictions. The characteristics of some mobile platforms are discussed and there is comparison between them and various wireless sensor nodes in order to examine their usage as biomedical sensor nodes in BWSN.

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II. Biomedical Sensor Nodes

The key components of BWSN are sensors, because they connect the physical world with electronic systems. They are mainly used to collect the information about physiology and the surrounding environment. Some of the sensor nodes have a sensor as their main part, and they are responsible for processing information by format conversion, data storage, logical computing, and transmitting. One sensor node generally comprises a sensor module, processor module, wireless communication module, and power supply module [4]. The sensor module is responsible for collecting the status of measurands and converting data from physical quantities to electrical signals.

The building blocks of BWSN are sensor nodes and consist four basic elements shown in Fig. 2: the sensor unit, processing unit, communication and power units.

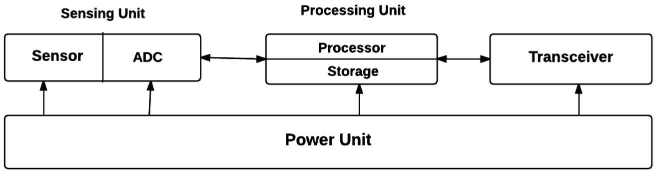

Fig. 2. Sensor Node architecture

Sensor nodes are the small, low power single board computers with a radio for wireless communication. Number and types of sensors depends on the applications. Sensor nodes collect and transfer data using four stages: collecting the data, processing the data, packaging the data and communicating the data [5].

Classification of Biomedical Sensors

In practical applications, the type of sensors and the number of sensors a BWSN system employs depend largely on the particular application scenario and system infrastructure [6]. Many different types of sensors can be used in BWSN, to complete the detection of physiology signals, human behavior, and the surrounding environment. Because of various application-specific requirements, the biosensors in BWSN can be of many types:

- *Depending on the type of measured signals:*

In [7] the authors divide sensors in BWSNs into two categories, according to the types of measured signals. The first category sensors collects signals continuously, placing more emphasis on real-time signal acquisition. The second category collect discrete time-varying physiology signals.

- *Depending on the types of data transmission media:*

One of the most commonly used biomedical sensors in BWSNs can be divided, depending on the types of data transmission media, into radio frequency identification devices (RFID), wireless sensors, which employ wireless communication technologies such as Bluetooth or Zigbee and Ultra Wideband (UWB). Removing wires completely will be an inevitable trend for BWSNs [8].

- *Depending on the deployment positions of sensor nodes:*

Biomedical sensors in BWSNs can be divided into three categories according to the deployment positions of sensor nodes [8]: sensors, which can be implanted into the body, such as a camera pill, called implantable; wearable sensors, such as accelerometers, temperature sensors and pressure sensors; sensors which can be used to recognize behaviors and collect information about the surroundings is placed surrounding peoplesuch as visual sensors.

- *Depending on the automatic adjustment ability:*

Biomedical sensors can be divided into two types, according to their automatic adjustment ability: self-adapting and non-self-adapting sensors. First type can automatically adjust processing method, order, and parameters, boundary conditions or constraints according to data characteristics, make themselves adapt to the statistical distribution and structural characteristics of the measured data, in order to get the best treatment effect. Second type are simple to design and need no consideration of self-adjusting function, and they are widely used in BWSNs at present.

- *Depending on the role in the network:*

Sensors in BWSNs can also be classified into three types based on their role in the network: Coordinator which is a gateway to the outside world or another BWSN; End Sensors which are only capable of performing their embedded application; Routers are intermediate sensors which have a parent sensor and a few child sensors through which they relay messages.

III. Mobile Platforms

The use of IoT standards in BWSNs allows the system designer to re-use application layer programs; presenting sensing data and actuation commands to software developers in a generic manner. The challenges however remains for BWSN designers operating at the gateway level and sensor network level.

A sensor node is a smart sensor that is capable of gathering sensory information, performing some processing, and communicating with other connected nodes on the network. Sensor platforms such as Arduino allow users to connect sensor and communications modules to a base platform. Gateways perform protocol translation between different networks. A gateway can operate at any network layer, and, unlike a router or a switch, a gateway can communicate using more than one protocol. PCs, servers, and M2M devices can function as gateways, although they are most commonly found in routers. In a sensor network, a gateway is responsible for interfacing the data from the sensor nodes to another network that uses a different protocol, and delivering commands back from that network to the nodes.

Mobile platforms, also called Single board computers (SBCs), that use a Linux based operating system provides the benefits listed below: Re-usable operating system drivers for networking, file storage and other peripherals; An abundance of software packages are readily available and actively maintained to accelerate functional software component development; Gateway devices can be monitored and administered with existing IT infrastructure monitoring systems; IT network administrators already have the necessary skills to implement and maintain Linux-based devices; Gateway hardware can be exchanged for a more powerful solution in a domain specific application; improving the flexibility of the solution.

Using the system design and key benefits listed above the Raspberry Pi, BeagleBone Black and Arduino Uno (Fig. 6) was selected for comparing with sensor nodes used in BWSN.

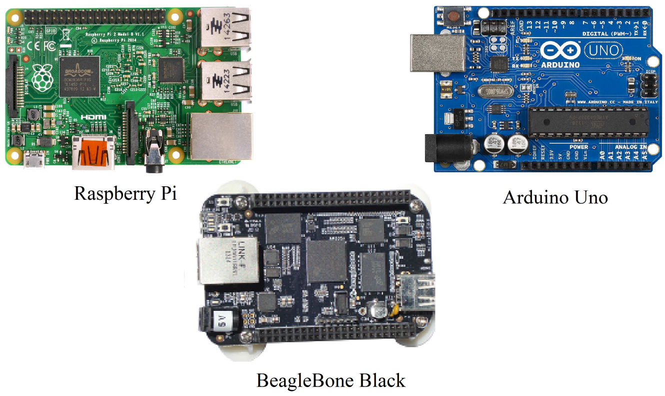

Fig. 6. Mobile Platforms

All these devices are popular mobile platforms for experimental use and run a Linux kernel based operating system. The logical separation of software and hardware components is a key requirement for scalability, cost and performance.

On the following table is shown a comparison between the mentioned mobile platforms and other similar boards.

TABLE I
THE COMPARISON BETWEEN MOBILE PLATFORMS

Features	Raspberry Pi - B	BeagleBone	Arduino	Panda Board	BeagleBone Black	Intel Galileo	MK802IIIS
SoC	Broadcom BCM2835	TI Sitara AM335x	Atmel ATmega328P	TI OMAP4460	TI Sitara AM335x	Intel Quark SoC X1000	Allwinner A10
Singlecore/ Multicore frequency	Single-core/ 700 MHz	Single-core/ 720 MHz	Single-core/ 16 MHz	Dual-core/ 1,2 GHz	Single-core/ 1 GHz	Single-core/ 400 MHz	Single-core/ 1 GHz
Networking	Ethernet	Ethernet	No	Ethernet/ Wi-Fi	Ethernet	Ethernet	Wi-Fi
RAM	512 MB	256 MB	2 KB	1 GB	512 MB	256 MB	1 GB
Price	0 - 49 $	50 - 79 $	0 - 49 $	400 $	50 - 79 $	50 - 79 $	50 - 79 $

Raspberry Pi is a small, powerful, cheap, hackable and education-oriented computer board. The platform contains a processor and graphics chip, program memory (RAM) and various interfaces and connectors for external devices [9]. Like any other computer, the Raspberry Pi also uses an operating system and the “stock” OS is a flavor of Linux called Raspbian. Linux, as a free and open source program, is a great match for Raspberry Pi [5].

BeagleBone Black is a single-board computer based on low-power Texas Instruments processors, using the ARM Cortex-A8 core. It is a small credit card-sized computer which can run an operating system such as Linux/Android 4.0. The main difference between it and Arduino is that it can run a small operating system, thereby practically converting it into a minicomputer that can run programs on these operating systems. BeagleBone is designed to function at a much higher l10el and it has far more processing capacity than Arduino.

Arduino is an open-source physical computing platform based on a simple microcontroller board, which can affect its surroundings by controlling lights, motors, and other actuators. The microcontroller on the hardware board can be programmed using the Arduino programming language and the Arduino Integrated Development Environment (IDE). Arduino supports two working modes, stand-alone or connected to a computer via USB cable [11].

IV. MOBILE PLATFORMS’S PERFORMANCES AND CONSTRAINTS

In next steps mobile platforms performances will be compared with following wireless sensor nodes [12]:

- MicaZ – is based on the Atmel ATmega128L which isa low-power microcontroller and runs MoteWorks from its internal flash memory.
- TelosB - bundles all the essentials for lab studies into a single platform including: USB programming capability, an IEEE 802.15.4 radio, a low-power MCU with extended memory and an optional sensor suite
- Iris – is used for enabling low power WSN.
- Cricket - is a location aware version of the popular MICA2 low-power Processor/Radio module.
- Lotus - is based on the NXP LPC1758, 32-bit ARM Cortex-M3 based microcontroller.

A. Size & Cost

The physical size and cost of each individual sensor node has a significant and direct impact on the ease and cost of deployment. Physical size impacts the ease of network deployment because smaller nodes can be placed in more locations and used in more scenarios. One of the main goals of every network is to collect data from as many locations as possible without exceeding fixed budget. A reduction in per-node cost will result in the ability to purchase more nodes, to deploy a collection network with higher density, and to collect more data. The comparison of size, weight and cost is given in Table II (the smaller values are better).

TABLE II
THE COMPARISON OF SIZE, WEIGHT AND COST

Name	Size (mm)	Weight (g)	Cost per node US$
Raspberry Pi	85.6*53.98*17	45	25-35
BeagleBone Black	86.3*53.3	39.68	45
Arduino (Uno)	75*53*15	30	30
MicaZ	58*32*7	18	99
TelosB	65*31*6	23	99
Iris	58*32*7	18	115
Cricket	58*32*7	18	225
Lotus	76*34*7	18	300

B. Power & Memory

The main goal of the biomedical sensor nodes is low power consumption in order to meet the multiyear application requirements. Also, algorithms and protocols must be developed to reduce radio activity whenever possible. This can be achieved by using localized computation to reduce the streams of data being generated by sensors and through application specific protocols.

The CPU is the main component of the mobile platforms, responsible for carrying out the instructions of a computer program via mathematical and logical operations. Regarding the storage, the device should have sufficient memory in order to store the collected data.

Comparative analysis of platforms and sensor nodes's CPU, memory and power is given in Table III.

TABLE III
THE COMPARISON OF CPU, MEMORY* AND POWER

Name	Processor	RAM	External memory	Power
Raspberry Pi	ARM BCM2835	256-512 MB	2-64 GB	5V/ USB
BeagleBone Black	AM335x 1GHz ARM® CortexA8	512 MB	4 GB	5V/ USB
Arduino	ATMEGA8, ATMEGA168, ATMEGA328, ATMEGA1280	16-32 KB	32 KB	7-12V /USB
MicaZ	ATMEGA128	4 KB	128 KB	5 V
TelosB	TI MSP430	10 KB	48 KB	5 V
Iris	ATMEGA1281	8 KB	128 KB	5 V
Cricket	ATMEL128L	4 KB	512 KB	5 V
Lotus	ARM NXP LPC1758	64 KB	512 KB	5 V

* *(The higher value is better)*

C. Operating System

Sensor nodes run embedded software that samples the physical environment, load data, aggregates and communicate with higher level (peers or gateways). Regardless of the hierarchical approach each sensor node as well as mobile platforms, still needs a program, and the most common approaches to programming each sensor node, is to either program it using some form of operating system or to choose a higher level of abstraction. The operating systems vary from traditional operating systems in terms of goals and technique and each system differs substantially in the approach to memory protection, dynamic reprogramming, thread model, real-time features, etc.

The comparison of used operating systems by the mobile platforms and sensor nodes is shown in Table IV.

TABLE IV
THE COMPARISON OF OPERATING SYSTEMS

Name	Operating system	Programming language
Raspberry Pi	Raspbian, Ubuntu, Android, ArchLinux, FreeBSD, Fedora, RISC OS	C, C++, Java, Phyton
BeagleBone Black	Linux Angstrom	Arduino
Arduino	No	Arduino
MicaZ	Tiny OS, Mote Runner	No
TelosB	Tiny OS, Sos, Mantisos	No
Iris	Tiny OS, Mote Runner	No
Cricket	Tiny OS	No
Lotus	Rtos, Tiny OS	No

V. CONCLUSION

BWSNs and the arranging sensors in, on and around the human body, realizes the detection of human action and physiological information, which has been widely used in the fields of health care, social welfare, sports, entertainment, etc. The ubiquitous network is coming with the method of taking human body as a part of the communication network. One of the main issues in BWSN is the design of sensor nodes, which should be paid to node size minimization and energy consumption reduction.

Mobile platforms's performances are compared with are compared with some popular sensor nodes on a general level by computing power, size and overall costs of the solutions. Based on performed analysis, it can be stated that Raspberry Pi has the best performances among considered mobile platfrms. The ultra-cheap-yet-serviceable computer board, with support for a large number of input and output peripherals, and network communication is the perfect platform for interfacing with many different devices and using in wide range of applications. In other words, the Raspberry Pi brings the advantages of a PC to the domain of sensor network, what makes it the perfect platform for interfacing with wide variety of external peripherals.

Even there are large differences between stated platforms in their ideal use cases, energy requirements, OS, etc., it can be noted that all of them can be very successively applied as biomedical sensor nodes.

REFERENCES

[1] F. Ali, "A Middleware to Connect Software Applications with Sensor Web", The International Journal of Technology, Knowledge and Society Volume 6, Number 5, pp. 27-35, 2010.

[2] Ullah S., Higgins H., Braem B. A Comprehensive Survey of Wireless Body Area Networks. Journal of Medical Systems, June 2012, Volume 36, Issue 3, pp 1065-1094.

[3] Robert Bogue, (2012) "Plessey launches range of unique electric field sensors", Sensor Review, Vol. 32 Iss: 3, pp.194 – 198.

[4] Ma, Q.; Hou, X.H. Study of wireless sensor node's structure. Sci. Technol. Inf. 2008, 24, 371–436.

[5] M. Richardson and S. Wallace, Getting started with Raspberry Pi, O'Reilly, USA, 2013.

[6] Liolios, C.; Doukas, C.; An Overview of Body Sensor Networks in Enabling Pervasive Healthcare. In Proceedings of the 3rd International Conference Greece, 23–25 June 2010.

[7] Gong, J.B.; Wang, R.; Cui, L. Research advances and challenges of body sensor network (BSN). J. Comput. Res. Dev. 2010, 5, 737–753.

[8] Chen, M.; Gonzalez, S.; Vasilakos, A.; Cao, H.; Leung, V.C.M. Body area networks: A survey. Mob. Netw. Appl. 2010, 16, 171–193.

[9] Frehill, P.; Chambers, D.; Rotariu, C. "Using Zigbee to Integrate Medical Devices", Engineering in Medicine and Biology Society, 29th Annual International Conference of the IEEE. Aug. 2007.

[10] M. Schmidt, Raspberry Pi – A Quick Start Guide, The Pragmatic Bookshelf, 2012.

[11] D. Uckelmann, M. Harrison, F. Michahelles, Architecting the Internet of Things, Springer 2011.

[12] M. Maurya, S. R. N. Shukla, "Current Wireless Sensor Nodes (Motes): Performance metrics and Constraints", Inter Journal.