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Why Software-Defined Radio (SDR) Matters in Healthcare?

Type of Article: Editorial

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Abstract

Background: Wireless Body Area Networks (WBANs) have been drawing noteworthy academic and industrial attention. A WBAN states a network dedicated to acquire personal biomedical data via cutting-edge sensors and to transmit healthcare-related commands to particular types of actuators intended for health purposes. Still, different proprietary designs exist, which may lead to biased assessments. This paper studies the role of Software-Defined Radio (SDR) in a WBAN system for inpatient and outpatient monitoring and explains to health professionals the importance of the SDR within WBANs.

Methods: A concern related to all wireless networks is their dependence on hardware, which limits reprogramming or reconfiguration alternatives. If an error happens in the equipment, firmware, or software, then, typically, there will be no way to fix system vulnerabilities. SDR solves many fixed-hardware problems with other benefits.

Results: SDR entails more healthcare domain dynamics with more network convergence in agreement with the stakeholders involved. Then the SDR perspective can bring in innovation to the healthcare subsystems' interoperability with recombination/reprogramming of their parts, updating, and malleability.

Conclusion: SDR technology has many utilizations in radio environments and is becoming progressively more widespread among all kinds of users. Nowadays, there are many frameworks to manipulate radio signals only with a computer and an inexpensive SDR arrangement. Moreover, providing a very cheap radio receiver/transmitter equipment, SDR devices can be merged with free software to simplify the spectrum analyses, provide interferences detection, deliver efficient frequency distribution assignments, test repeaters' operation while measuring their parameters, identify spectrum intruders and characterize noise according to frequency bands.

Keywords: Wireless Body Area Network (WBAN), Software-Defined Radio (SDR), Internet of Things (IoT), Healthcare.

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1. Introduction

A Wireless Body Area Network (WBAN) is responsible for the wireless Internet connection of independent nodes, each one of them comprising Control Units (CUs), sensors, and actuators that are situated in the clothes on the body or under the within the person's body. These devices are popularly known as wearables and permit several different topologies like a star or multi-hop.

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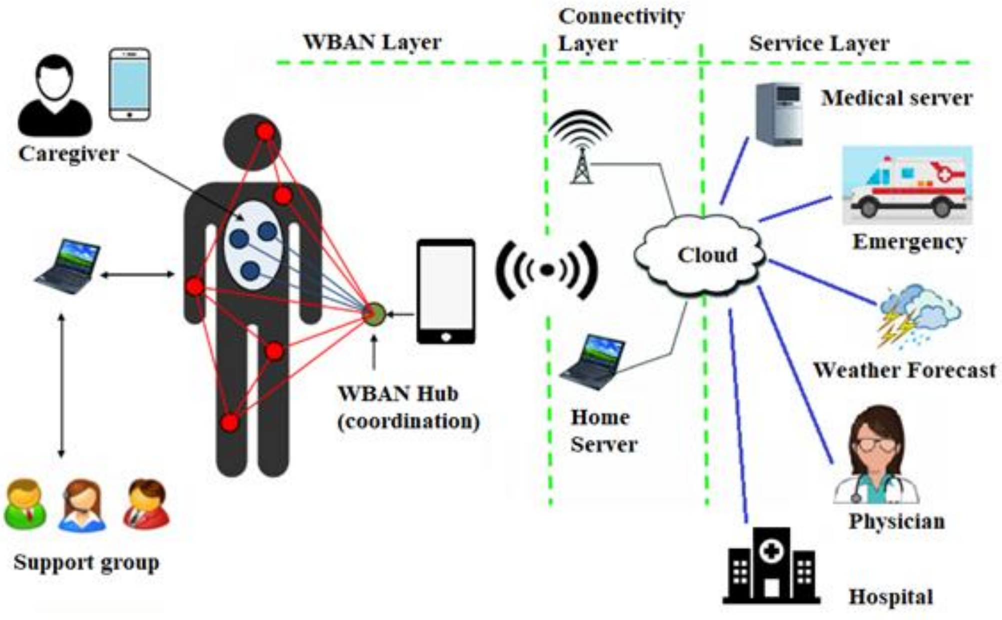

Figure 1. Diagram showing a WBAN.

A WBAN offers many promising new utilizations in remote healthcare monitoring, homecare, medicine, multimedia, sports, and several other usages, all of which take advantage of the unimpeded freedom that a WBAN offers. E.g., an ill person can wear a WBAN consisting of sensors that regularly measure specific biological functions, like blood pressure, temperature, respiration, heart rate, ECG, etc. [12-14]. The benefit is that the patient is away from bed and healthcare facilities, and move freely across the room. If he/she is an inpatient, then this person can even leave the hospital for a while. This paradigm change improves the patient's Quality of Life (QoL) and lessens hospital costs. Moreover, the data is acquired over an extended period and within the patient's natural environment, which offers more valuable information, and allows for better and, occasionally, even faster diagnosis. Along with the spread of mobile devices and wearables, the healthcare domain has seen the rapid progress of tools intended for the Internet of Things (IoT). Medical IoT devices include physiological monitors, biomedical devices, medical records repositories, mobile medical apps, and equipment for examinations like MRI, CT, and ultrasound. Several wearables for healthcare appeared in recent times to obtain data about parameters/vital signs such as temperature, heart rate, and acceleration to follow a person's activities and well-being [3]. These systems aid high-performance sports and remote monitoring of patients [5, 6]. These practices quite often rely on the ANT+ standard (ANT+S). This protocol lacks Bluetooth or Industry 4.0 compatibility, which has low-power consumption, with a low-transmission rate, and exists in smartphones [7].

1.1 ANT+ Standard

The trademarked Adaptive Network Topology (ANT+) is an open-access multicast technology for wireless sensor networks from the ANT Wireless [1] for sports and fitness sensors.

ANT defines a Wireless Communication (WC) protocol stack that permits hardware to utilize the 2.4 GHz Industrial, Scientific and Medical (ISM) radio band to communicate. ANT established standards for evidence representation, co-existence, signaling, validation, in addition to error discovery [3]. It is conceptually akin to Bluetooth regarding low energy despite the fact it favors its usage with sensors.

The ANT+ ultra-low-power WC standard implements an interoperability function. This feature supplements the underlying ANT protocol and simplifies the networking of neighboring ANT+ devices/subsystems to smooth the acquisition and analysis of sensory information [2]. Because healthcare wearables demand robustness and still call for more standardization, they may face changes, which may encounter obstacles since this standard is proprietary, and the information is not open to the public.

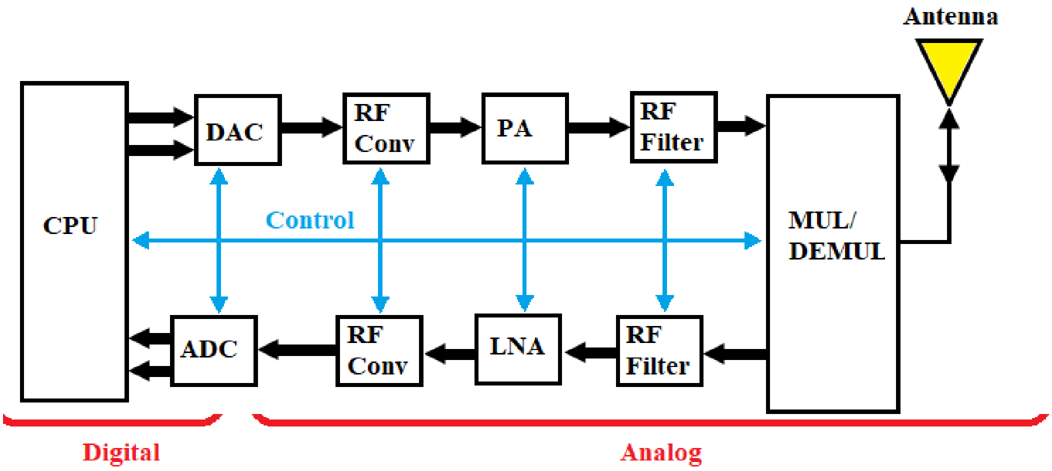

Figure 2. SDR block diagram with the receiver (lower part) and transmitter (upper part).

1.2 The Software-Defined Radio Role in Healthcare

Notwithstanding the multiple technological advances, a new and possibly challenging concern common to all wireless networks is the fact that their radio equipment and protocols rely mostly on hardware. Consequently, reprogramming or reconfiguration alternatives are very restricted. This inflexibility is bothersome because if an error happens in the equipment, firmware, or software, then, usually, there will be no practical way to correct the shortcoming due to the inherent system vulnerabilities. This feature limits the hardware components' functionality and reconfigurability to implement other WC protocols beyond the one predefined by the hardware. Precisely, the SDR solves many of the problems described previously, along with many other benefits. Therefore, the healthcare community necessitates better network convergence developments in agreement with the dynamics of the healthcare field and stakeholders involved. Meanwhile, the SDR perspective can bring in innovation to this context with subsystems' updating, interoperability, combination, and malleability.

The upcoming sections are organized as follows: Section 2 introduces the basics of Software-Defined Radio (SDR). Section 3 presents some thoughts for deploying healthcare WBANs. Future trends appear in Section 4. This work closes with a fifth Section containing the conclusions.

2. Software-Defined Radio (SDR)

The Software Defined Radio (SDR) is a WC design identified with a class of radio systems reprogrammable as well as reconfigurable via software.

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Nowadays, SDR software and hardware are available at meager prices. In terms of SDR software, most implementations are free. An SDR device appears in Figure 2.

Ultimately, the demodulator recuperates the original modulating signal from the Low-Noise Amplifier (LNA) output, employing one of several alternatives. Further signal processing depends on the purpose of the SDR equipment.

Figure 2 illustrates the SDR hardware framework block diagram. At first, the Radiofrequency (RF) tuner filter converts the analog signal to the Low-Noise Amplifier (LNA), then the necessary channel is isolated and converted from analog to digital by an Analog-to-Digital Converter (ADC). When the CPU finishes with processing, then the digital signal is transformed into an analog signal by a Digital-to-Analog Converter (DAC) and modulated for transmission. At the transmission path, some Power Amplification (PA) is necessary.

While the hardware elements are indispensable parts in the SDR rationale, the paradigm points out the need for complementary dedicated software. Some IDEs to develop an SDR-based WBAN software employing a computer or an FPGA or a CPU such as a Digital Signal Processor (DSP) is needed. Nevertheless, before developing software, a hardware framework must provide low-level interface functions. Major software IDEs are

(i) LabVIEW by National Instruments; and

(ii) MATLAB/ Simulink/ USRP by MathWorks.

3. Some Considerations for Deploying Healthcare WBANs

The use of WBANs is increasingly making a difference as healthcare facilities introduce additional Wi-Fi-based technology. WBANs are the essence of healthcare IT infrastructure, although designing and deploying dependable Wi-Fi for present and prospect IT initiatives can be a trial.

Healthcare personnel is becoming dependent on interconnected mobile devices that function relentlessly and everywhere. Since some of these devices are mission-critical, the risk of a service outage may disrupt operations or even threaten patient safety.

The arrangements required to support an entire IT infrastructure relying on IoT must make a serious inventory all physical and digital impediments, understanding the information flow with the corresponding devices/subsystems priorities to perform network connection, along with ways to conciliate network components visibility with its management. Some of the chief obstacles to WBANs deployments and organizations are as follows:

Coverage**:** Mobile gadgets and wearables call for reliable wireless internet connectivity regardless of the dislocations of the stakeholders. Network coverage means devices can work everywhere. The dynamic characteristics of healthcare experts strengthen this urgency. Healthcare personnel requires connectivity to use communication tools even when outside of buildings.

Structural Planning**:** Designing and realizing a wireless answer is more elaborate than deploying other portions of healthcare IT infrastructure due to frequent and numerous physical barriers, such as building materials that block RF signals. Urban hospitals may also have to struggle with conflicting signals stemming from other networks in the region. Healthcare facilities habitually entail retrofitting a wireless network to their physical installations instead of constructing edifices with particular wireless pre-requisites. Rather than deploying a completely upgraded infrastructure altogether, Healthcare establishments can work through departments, buildings, or systems, upgrading one system portion at a time until finishing the entire system. Newer wireless deployments like the IEEE 802.11ac [4] support legacy devices can still connect to the new system, and gadgets can take advantage of the full bandwidth and faster speeds.

Network Capacity**:** The snowballing number of devices asking access to wireless networks can impact legacy systems severely, leading to access problems. Once a healthcare organization receives basic network coverage, it must guarantee network robustness to fulfill the necessary expectations.

Information Quality**:** Data engendered and gathered through WBANs can influence the patient's healthcare process, which calls for a high standard to safeguard decision-making relying on the best possible records.

Data Control**:** As WBANs yield large data volumes, the necessity to manage and retain these healthcare datasets becomes of utmost importance.

Pervasive Device Validation**:** Sensors and actuators have inherent communication while being robust to hardware constraints such as unreliable network links, limited energy reserves, and interference. These limitations may provoke the incorrect transmission of datasets to the stakeholders. It is essential in a healthcare realm that all sensor measurements and actuator commands are validated to decrease false alarms and helps to recognize possible hardware and software flaws.

Data Consistency**:** Information from multiple mobile devices, media, and remote patient files need to be acquired and examined smoothly. Within WBANs, vital patient datasets may not arrive at their destination or contain corrupted packets after wandering over several nodes or places as well as through many networked computers. If a healthcare practitioner′s portable device does not hold all known data, then the healthcare quality may worsen.

Security**:** To make WBAN transmission safe and accurate, one has to guarantee that the patient data is secure and that each patient possesses a dedicated WBAN to avoid his/her information to mix up with different patients. Moreover, the WBAN data must be secure and with limited access.

Resource Availability**:** As WBANs face resource-constrains because of energy, memory, communication rate, and computational competence, security solutions from other varieties of networks may not apply to WBANs [14, 17].

Interoperability**:** The 802.15.6 standard governs the WBAN configurations. These regulations outperform current WC knowhow such as Bluetooth and ZigBee. This standard partakes the benefits of ultra-low-power consumption, high reliability, and high-security protection while transferring sensitive personal data. WBAN structures call for seamless data transferences across other norms, e.g., Bluetooth, ZigBee, and the IEEE 802.15.6 [9] standards to stimulate data exchange in a plug-and-play fashion with scalability, guaranteed efficient migration throughout networks and nonstop connectivity.

System Sensors and Actuators**:** The WBAN sensors should have low complexity, small size, light, easy to use, power-efficient, and reconfigurable. Furthermore, the data storage requires some local redundancy, remote storage via cloud, access to patient data, and to external processing via the Internet [12].

Privacy**:** WBANs should not threaten the stakeholder's freedom if facing unexpected situations through medical usage. Confidentiality, availability, authentication, trustworthiness, and novelty of data together with secure information management requirements for WBAN exist in the IEEE 802.15.6 standard [5].

***Interference*:** The wireless links from body sensors should lessen the interference, coexist with other WBAN devices, and allow scalability to facilitate further connection of other network devices, especially for large-scale WBAN implementations [18].
***Cost*:** Healthcare consumers want low-cost health surveillance solutions with high functionality. Cost-optimized WBAN deployments will appeal to health-conscious people.
***Monitoring*:** Patients may entail different observing priorities. E.g., cardiopaths may need checking up functions working nonstop, while elders at risk of falls may function at a lower priority while walking or moving. The monitoring type affects the amount of power required to sustain the WBAN framework.
Constrained Deployment: The WBAN has to be non-intrusive, wearable, and lightweight so that it should not alter or hinder the patient's and his/her caregiver's daily activities.
***Consistent Performance*:** The WBAN performance should be reliable so that sensor inputs and actuator outputs are precise and calibrated even when the patient's WBAN has been off for some time, and it is switched on again. The WC links should be robust and perform under various patients' situations.
Quality of the Healthcare Service: Healthcare organizations can assess their environments for a possible wireless network upgrade employing surveys are an option [13, 16]. A site assessment can perceive the parts that experience problems with signal reception and transmission. Site surveys support healthcare organizations in successfully assigning Access Points (APs) according to the existent needs and without wasting resources on redundant/unnecessary APs.

4. Future Trends

The majority of the radio equipment is located in Europe and North America, although there are stations on all continents. The operating bands and the signal's quality may differ from one location to another, which is understandable if the spontaneous nature of the network is considered. Still, by accessing numerous nodes, multiple bands can be enclosed, especially in high-density areas.
The SDR-based Internet possibilities discussed previously point towards the following applications of the technology [11]:
***Estimation of Wireless Transmission Losses*:** If there is centralized control of SDR devices deployed at strategic points to enable the signals' comparison at reception, then the estimation of path loss and the validation of the coverage computations made with specialized software like RadioMobile [8] can be done.
***SDR as a Service*:** The healthcare corporation deploying a vast SDR network will be able to make access available as a service to other parties with specific interests.
***Impact of the Geographical Site*:** Emitters' locations can be obtained from the evidence supplied by several receivers situated distantly. If at least three of them are used, the radiofrequency source location can be accurately determined. Nonetheless, the deployment is not straightforward with the software presented [10].
***Improvement of Shortwave Communications*:** Employing remote SDR receivers make shortwave transmissions available even from distant countries, which expands the HF communication quality through the Internet.
***Spectrum Exploring*:** To listen to specific bands in faraway localities can be advantageous for many organizations.

5. Conclusion

SDR technology has various usages in relying on radios and is progressively more widespread among all kinds of users. Nowadays, there are many frameworks to manipulate radio signals employing only a computer with a low-cost SDR arrangement to obtain an economical radio receiver/transmitter framework. Free software helps to deploy SDRs that simplify the spectrum analyses, afford interference detection, allocate efficient frequency distribution, examine repeaters' operation while assessing their parameters, pinpointing spectrum intruders besides typifying noise according to the frequency bands [18-20].

6. Conflict of interest statement

We certify that there is no conflict of interest with any financial organization in the subject matter or materials discussed in this manuscript.

7. Authors' biography

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