

## *Editorial*

Special Section in *IEEE Access*:

### **Body Area Networks**

The present Special Section of the *IEEE Access* on Body Area Networks (BAN) collects the extended versions of the best manuscripts submitted to and presented at the “Bodynets 2016”, a conference that “aims to provide a world-leading and unique opportunity for bringing together researchers and practitioners from diverse disciplines to plan, analyze, design, build, deploy and experiment with/on Body Area Networks (BANs)” <http://bodynets.org/2016/show/home>, held in December 2016 in Torino, Italy.

Recent findings in BAN related bio-medical engineering research, in the fields of electronics, medicine, materials science, electromagnetics, signal processing, computing, etc. and more importantly the significance of the inter-disciplinary aspects between them that provides a successful solution are put together through 13 high quality publications authored by experts from all around the globe (USA, Germany, China, Finland, Italy, etc.). At the time of the preparing of this editorial, many of the papers have already received a very large number of views, clearly demonstrating the challenging of the considered subject.

Some papers have tried to answer to the novel requirements of the healthcare sector facing, among other issues, the strong demographic changes associated to elderly population that put researchers in front of new and exciting challenges. Advanced electronic and networked systems allowing real time monitoring can strongly reduce medication time and costs. Timely intervention of physicians on individuals living alone (and whose number is constantly increasing), or in remote areas, is possible if appropriate data transmission infrastructure is guaranteed. One part of this complex architecture is the so-called Body Area Network (BAN), i.e. the part of the communication infrastructure that directly interacts with the human body. It should be able to support both the sensing part, connected to the relative data transmission from the person under inspection to the physician, and the possibility to receive notifications and/or alerts once the data have been processed. Such technologies are already starting to enter into routine clinical practice. However, novel technologies such as nano-communication, intra/extra body communication, and others open the door for more and more accurate future diagnostics. Today research activity is strongly driven by non-invasive exploration of living bodies. Wide-band reflectometry using adequate antennas system represents a possible way, but sometimes more accuracy, which can be achieved by the use of implantable sensors that can more closely investigate the interested tissues and are able to communicate with the external systems, is required. For some applications, this communication can be unidirectional for monitoring purposes, but even in these cases, the transceiver should be carefully designed to obtain the necessary data while generating as low as possible radiofrequency power within the tissues. The received signal is processed locally or sent to a remote medical center for further processing. The algorithms to extract the information are quite complex, and the low signal-to-noise ratio makes the analysis even more

challenging. A bi-directional communication on the other hand represents a considerable advancement, when the sensor nodes are remotely controlled based on the feedback of the received data, for controlled drug release applications, as an example. Nevertheless, the reduced transmitter-receiver distance and the presence of different high-loss tissues introduce strong reflections. Healthcare is very likely the main but not the only application domain for BANs. Wellness, social interactions, emergency and rescue, as well as military are other important application areas for BANs; all of them would profit from advances in BANs and in how BANs will be developed and deployed in real-working, even large scale, testbeds.

The invited paper of Felicetti, *et al.*, (Congestion Control in Molecular Cyber-Physical Systems) discusses the performances of a new class of engineered systems based on interactions between cyber and physical components, by integrating three main components: communications, control, and computing. When these systems are brought to the nanoscale, some design and implementation issues arise. A high level of complexity is due to the use of biological components in a cyber-physical system (CPS), such as engineered cells, which may play the role of sensors, actuators, or even controllers. In this paper, the study of the effectiveness of control solutions implemented through the usage of molecular communications in a biological nanoscale CPS, where a biological nanomachine plays the role of actuator that releases drug molecules, and the another acts as both sensor and controller, is discussed

The paper by Davis, *et al.*, (Effects of Ambient Lighting Displays on Peripheral Activity Awareness), which received the best conference paper award, discusses the development of “smart” everyday objects, which offer tremendous opportunities for maintaining the quality of life in ambient assisted living (AAL) environments. In particular a peripheral activity-based awareness system that captures human activity information and renders this information to enhance context awareness and support social connectedness between the elderly and their caregivers has been envisaged.

Li, *et al.*, (A Neuro-fuzzy Fatigue-tracking and Classification System for Wheelchair Users) discuss the functionalities of smart wheelchairs as mobility assistive equipment issues related to the world widely increasing elderly and disabled population. The paper suggests a neuro-fuzzy fatigue tracking and classification system and applies this method to classify fatigue degree for manual wheelchair users, considering both physiological and kinetic data, collected by surface electromyography, electrocardiography, and acceleration signals. The necessary features are then extracted from the signals and integrated with a self-rating method to train the neuro-fuzzy classifier.

Reliability is one of the most important communication metrics in wireless BANs especially for medical applications. However, traditional one-hop transmission power control methods failed to guarantee the reliability when the transmission distance is large. Zhang, *et al.*, (A Relay-aided Transmission Power Control Method in Wireless Body Area Networks) propose a relay-aided transmission power control method providing reliable transmission and simultaneously alleviating the relaying burden on relay nodes. The proposed technique automatically switches transmitter's transmission strategy between the direct transmission and the relay-aided transmission based on the channel condition to consider long distance problem and then adaptively adjusts the transmission power according to the received signal strength indicator feedback to guarantee the reliable transmission as much as possible and conserve the energy of relay nodes. Additionally, in the proposed method, parameters are tunable according to the application scenarios to make tradeoff between reliability and energy efficiency.

The paper authored by Genovese, *et al.*, (A Smartwatch Step Counter for Slow and Intermittent Ambulation) is concerned with the development and the preliminary validation of a step counter (SC) designed to operate also in conditions of slow and intermittent ambulation. The SC is based on processing the

accelerometer data measured by a Gear 2 smartwatch running a custom wearable app. Data are compared with two different commercial SCs, and an error is limited to 5%, which is significantly lower than errors of 20%-30% incurred by the two other SCs.

Wu, *et al.*, (An Autonomous Wireless Body Area Network Implementation Towards IoT Connected Healthcare Applications) proposes a wearable sensor node with solar energy harvesting and Bluetooth low energy transmission that enables the implementation of an autonomous wireless BAN (WBAN). Multiple sensor nodes can be deployed on different positions of the body to measure the subject's body temperature distribution, heartbeat, and to detect falls. A web-based smartphone application is also developed for displaying the sensor data and fall notification. To extend the lifetime of the wearable sensor node, a flexible solar energy harvester with an output-based maximum power point tracking technique is used to power the sensor node. Experimental results show that the wearable sensor node works well when powered by the solar energy harvester. The autonomous 24h operation is achieved with the experimental results. The proposed system with solar energy harvesting demonstrates that long-term continuous medical monitoring based on WBAN is possible provided that the subject stays outside for a short period of time in a day.

Through 154 references, Särestöniemi, *et al.*, (An Overview of the Electromagnetic Simulation Based Channel Modeling Techniques for Wireless Body Area Network Applications) present a general overview, including recent progresses, of the electromagnetic simulation-based WBAN channel modeling techniques. Advantages, disadvantages, and the most appropriate applications are described. Furthermore, the features of the different techniques are compared.

The paper of Zhang, *et al.*, (HeartID: A Multiresolution Convolutional Neural Network for ECG-based Biometric Human Identification in Smart Health Applications) presents some application of the BAN related to health applications in the new era of smart cities. To meet increasing security and privacy requirements, physiological signal based biometric human identification is gaining tremendous attention. To enable a data-independent and highly generalizable signal processing and feature learning process, a novel wavelet domain multiresolution convolutional neural network is proposed, which allows for blindly selecting a physiological signal segment for identification purpose, avoiding the intricate signal fiducial characteristics extraction process.

Matekovits, *et al.*, (Mutual Coupling Reduction between Implanted Microstrip Antennas on a Cylindrical Bio-metallic Ground Plane) propose and compare different methods to reduce the mutual coupling between two antennas within a multilayer cylindrical body model that includes highly lossy body tissues into which a biocompatible metal implant is inserted. This cylindrical bio-metal implant serves as the common ground plane for the conformal low profile antennas. The mutual coupling between two such conformal microstrip antennas is studied and quantified for different spacing between them.

Properties of the next generation of cooperative wearables are the topic of the paper authored by Seiffert, *et al.*, (Next Generation Cooperative Wearables: Generalized Activity Assessment Computed Fully Distributed within a Wireless Body Area Network). More in detail, a generalized trainable activity assessment chain (AAC) for the online assessment of periodic human activity within a WBAN is presented. Qualitative assessment with human knowledge by projecting the AAC on the hierarchical decomposition of motion performed by the human body as well as establishing the assessment on a kinematic evaluation of biomechanically distinct motion fragments is performed.

The challenging topic of antenna placement on the body is studied by Brumm, *et al.*, (On the Placement of On-Body Antennas for Ultra Wideband Capsule Endoscopy). Ultra wideband communication is proposed as an alternative to increase the data rate for in-body to on-body communications compared with existing narrowband standards. Since there are no reproducible models available in literature that enable the calculation of the channel capacity, a new channel modeling technique based on a plane wave propagating through a multi-layered dielectric is proposed and discussed. Results show that a single receive antenna gives nearly no improvement compared to existing standards. However, if the number of antennas is increased to 5, the 10%-outage capacity can be improved by several orders of magnitude.

In recent years, cloud-assisted body area network technologies have made their entrance in the Smart healthcare field, such as Smart home environment, and play a significant role for healthcare data storage, processing, and efficient decision making. The paper written by Hassan, *et al.*, (Resource Provisioning for Cloud-Assisted Body Area Network in a Smart Home Environment) is related to this hot-topic, where they consider a fast and robust cloud resource allocation model for body sensor devices to ensure Quality of Service (QoS) for Smart home healthcare applications. The proposed resource allocation algorithm is developed using agent-based modeling (ABM) and ontology. The results from the implementation are compared with those of existing algorithms and found to be promising.

A subject-adaptive unsupervised signal compressor for wearable fitness monitors is proposed by Hooshmand, *et al.*, (SURF: Subject-adaptive Unsupervised ECG Signal Compression for Wearable Fitness Monitors). Recent advances in wearable devices allow non-invasive and inexpensive collection of biomedical signals including electrocardiogram (ECG), blood pressure, and respiration, among others. Collection and processing of various biomarkers are expected to facilitate preventive healthcare through personalized medical applications. The proposed method leverages unsupervised learning techniques to build and maintain, at runtime, a subject-adaptive dictionary without requiring any prior information on the signal, giving rise a reduce energy consumption, hence a longer service time. The algorithm, with artifact prone ECG signals, allows for typical compression efficiencies (CE) in the range  $CE \in [40, 50]$ , which means that the data rate of 3 kbit/s that would be required to send the uncompressed ECG trace is lowered to 60 and 75 bit/s for  $CE = 40$  and  $CE = 50$ , respectively.

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- 1) Zhelong Wang Professor, Dalian University of Technology, Cina.
- 2) Hassan Ghasemzadeh, Assistant Professor, Washington State University, USA.
- 3) Valeria Loscri, Researcher, INRIA, France.
- 4) Ildiko Peter, Researcher, Politecnico di Torino, Italy
- 5) Matti Hämäläinen, Adjunct Professor, University of Oulu, Finland.

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