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Editorial

Energy and Spectrum Efficient Wireless Sensor Networks

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Global warming, a result of rising greenhouse gas (GHG) emissions levels, is a major challenge that the industrial society needs to address. Parties to the United Nations Framework Convention on Climate Change (UNFCCC), held in Paris in 2015, agreed that significant cuts in GHG emissions are required and that future global warming should not exceed 2.0°C relative to the preindustrial levels [1].

Among others, the Information and Communications Technology (ICT) industry is one of the most rapidly growing emitters of GHG pollution and consumers of electrical power. According to global consultants Gartner [2], it presently accounts for approximately 0.86 metric gigatonnes of carbon emissions annually (about 2% of global carbon emissions), and its carbon footprint grows at a worrisome rate. The need for green ICT technologies is thus becoming more urgent day after day.

At the same time, the radio-spectrum shortage is emerging as a major concern for service operators and system designers. Indeed, in the last few years the growth of mobile data traffic has been almost incredible; Cisco predicts that by 2019 it will have grown to 24 exabytes (1 exabyte = 1 billion gigabytes) per month. Already in 2010 the FCC Chairman Genachowski stated [3]: "*The explosive growth in mobile communications is outpacing our ability to keep up. If we don't act to update our spectrum policies for the 21st century, we're going to run into a wall – a spectrum crunch.*" In fact, similarly to more traditional raw materials, such as iron or oil, there is a finite amount of spectral resources. This means that the only reasonable way to cope with such a threat is to use the existing spectrum more efficiently.

With particular reference to wireless sensor network (WSN) technologies, addressed in this special issue, both the energy efficiency and the spectrum efficiency are of paramount importance. Even putting aside environmental issues, in fact, WSNs are usually battery powered, with obvious requirements in terms of energy consumption. Moreover, these technologies primarily operate in the unlicensed Industrial, Scientific, and Medical (ISM) bands, which are shared with other popular wireless systems. As the number of users and communication technologies increases, the ISM bands are becoming increasingly congested and the coexistence issue is becoming more and more critical. The key point is how to minimize the mutual interference and maximize the spectrum utilization. The objective of this special issue is to present recent progress in the area of spectrum and energy efficient WSNs. The following papers were selected from a much larger set of submissions.

In the paper "Efficient Aerial Data Collection with UAV in Large-Scale Wireless Sensor Networks," the authors designed a basic framework for aerial data collection that includes the following five components: deployment of networks, nodes positioning, anchor points searching, fast path planning for Unmanned Aerial Vehicles (UAVs), and data collection from networks. They identified the key challenges in each of them and proposed efficient solutions. This includes the proposal of a Fast-Path-Planning-With-Rules (FPPWR) algorithm based on grid division to increase the efficiency of path planning, while guaranteeing the length of the path to be relatively short. They also designed and implemented a simulation platform for aerial data collection from WSNs and validated the effectiveness of the proposed framework based on the following parameters: time consumption of the aerial data collection, flight path distance, and volume of collected data.

In the paper "Improving Energy Efficiency in QoS-Constrained Wireless Sensor Networks," the authors provided a survey of the most recent works on energy efficiency in WSNs and discussed the impact of the proposed methods on the Quality of Service (QoS) provided. Moreover, they proposed a novel divide-and-conquer procedure to deal with the trade-off between energy consumption and QoS parameters. The idea is to tackle a certain source of energy consumption to minimize the drawn energy. Subsequently, this energy-saving method is refined to consider other service qualities. To support the correctness of their claim, three energy-saving methods, taking the QoS issues into consideration, are given as examples. The first method exploits a so-called fuzzy transform for shrinking the wireless traffic with highly precise lossy data compression. In the second method, the sensing module is targeted by employing reliable virtual sensors. Such sensors compensate the unavailability of main energy-hungry sensors during sleep periods. The third method exploits a self-adaptive mechanism to improve the QoS parameters via deliberately reducing the lifetime below the maximum time, with the only constraint of the application expected lifetime.

In the paper "An Energy Efficient Anchor-Free Localization Algorithm for No-Identity Wireless Sensor Networks," the authors proposed an efficient anchor-free localization algorithm for WSNs without identification information. Collecting information from nodes in WSNs and positioning calculation usually require a large number of communications. The localization algorithm proposed in this paper reduces the required transmissions and associated energy consumption by making use of the positioning information transmitted by the sink node, without depending on anchors. The localization accuracy as well as energy efficiency was verified by experimental design in comparison to conventional positioning algorithms, which proved the effectiveness of the proposed solution.

In the paper "An Energy-Efficient Transmission Protocol for RNC-Based Cooperative WSNs with Partial Energy Harvesting Nodes," the authors addressed the energy efficient transmission for the scenario of cooperative WSNs with partial energy harvesting (EH) nodes. A new EH decoding-recoding policy is proposed by regarding the EH constraints and the characteristics of random network coding. They developed an energy efficiency model to investigate the trade-off mechanism between the saved energy and the waiting time of the EH node, through which the corresponding parameters in the policy are also optimized. Moreover, they proposed a novel transmission protocol by embedding the considered policy into the opportunistic reception algorithm. The decoding failure probability is then derived to examine its transmission reliability. The obtained theoretical and simulation results indicate that the proposed protocol achieves superiority in energy efficiency; meanwhile, it can also provide similar transmission reliability under specific conditions, as compared to the conventional algorithms in the two-hop model.

In the paper "An Efficient Distributed Scheduling Algorithm for Mobility Support in IEEE 802.15.4e DSME-Based Industrial Wireless Sensor Networks," the authors evaluated, at first, the performance of the industrial Medium Access Control (MAC) for WSNs based on IEEE 802.15.4e by using various mobility scenarios for smart factory environments. They also proposed an IEEE 802.15.4e scheduling algorithm for mobility support that is based on distributed synchronous multichannel extension (DSME) and measured various performance metrics. The proposed algorithm can adaptively assign communication slots by analyzing the network traffic of each node and improve the network reliability and timeliness. The experimental results showed that the throughput of the DSME MAC protocol is better than the IEEE 802.15.4e time-slotted channel hopping (TSCH) and legacy slotted Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) in large networks with more than 30 nodes. The proposed algorithm also improves the throughput by 15% compared with other MACs including the original DSME. The algorithm was experimentally confirmed to reduce power consumption by improving the availability of communication slots.

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