IJCSE International Journal of Computer Sciences and Engineering Open Access
Review Paper Vol.-7, Issue-1, Jan 2019 E-ISSN: 2347-2693

Compliances of Connectivity and Communication strategies of Wireless Sensor Network (WSN) over IoT

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Available online at: www.ijcseonline.org

Accepted: 20/Jan/2019, Published: 31/Jan/2019

***Abstract*:** Wireless sensor networks (WSNs) enable new applications and require nonconventional paradigms for protocol design due to several constraints. Owing to the requirement for low device complexity together with low energy consumption (i.e., long network lifetime), a proper balance between communication and signal/data processing capabilities must be found. This motivates a huge effort in research activities, standardization process, and industrial investments on this field since the last decade. This survey paper aims at reporting an overview of WSNs technologies, main applications and standards, features in WSNs design, and evolutions with connections of Internet of things. The Internet of Things, or IoT, refers to the set of devices and systems that interconnect real-world sensors and actuators to the Internet. Emphasis is given to the IEEE 802.15.4 technology, which enables many applications of WSNs. Some example of performance characteristics of 802.15.4based networks are shown and discussed as a function of the size of the WSN and the data type to be exchanged among nodes.

***Keywords*:** WSN, IoT, nodes, gateway, self-organizing singlesink WSN, PPP, event detection, spatial process estimation etc.

I. INTRODUCTION

A WSN can be defined as a network of devices, denoted as nodes, which can sense the environment and communicate the information gathered from the monitored field through wireless links. The data is forwarded, possibly via multiple hops, to a sink (sometimes denoted as controller or monitor) that can use it locally or is connected to other networks (e.g., the Internet) through a gateway. The nodes can be stationary or moving.

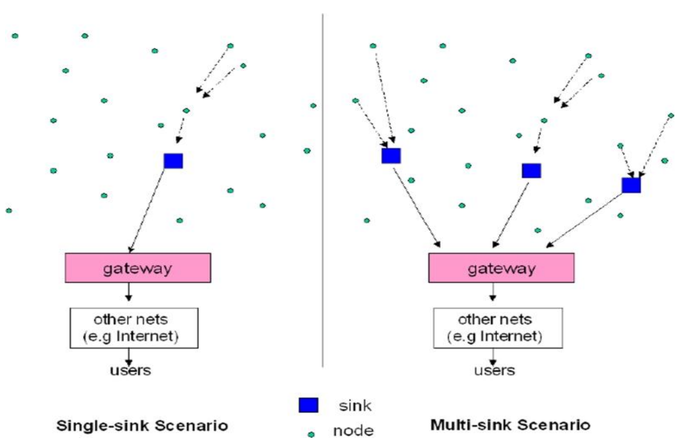

Fig.1

This singlesink scenario suffers from the lack of scalability. They can be aware of their location or not. They can be homogeneous or not. This is a traditional singlesink WSN. (Fig.1). Almost all scientific papers in the literature deal with such a definition. The sink increases and once its capacity is reached; the network size cannot be augmented. Moreover, for reasons related to MAC and routing aspects, network performance cannot be considered independent from the network size. The variety of possible applications of WSNs to the real world is practically unlimited, from environmental monitoring, health care, positioning and tracking, to logistic, localization, and so on. A possible classification for applications is provided in this section. One of the possible classifications distinguishes applications according to the type of data that must be gathered in the network. Almost any application, in fact, could be classified into two categories: event detection (ED) and spatial process estimation (SPE). In the recent literature, different works addressed the estimation of a scalar field using random WSNs. As an example, presents a distributed algorithm able to estimate the gradient of a generic smooth physical process (energy constraints and nodes failure are not considered there).

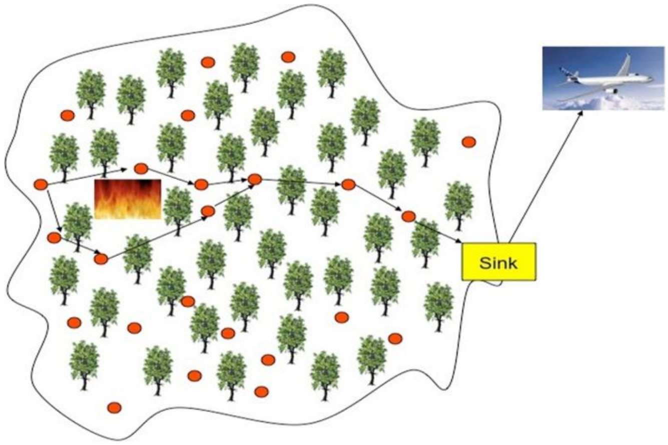

Fig.2

There exist also applications that belong to both categories. As an example, environmental monitoring applications could be ED or
SPE based. To the first category belong, for example, the location of a fire in a forest, or the detection of a quake, etc (Fig2). Alternatively, the estimation of the temperature of a given area belongs to the second category. In general, these applications aim at monitoring indoor or outdoor environments, where the supervised area may be few hundreds of square meters or thousands of square kilometers, and the duration of the supervision may last for years.

II. THEORETICAL CONSIDERATIONS

Due to the wide variety of possible applications of WSNs, system requirements could change significantly. For instance, in case of environmental monitoring applications, the following requirements are typically dominant: energy efficiency, nodes are battery powered or have a limited power supply; Low data rate, typically the amount of data to be sensed is limited; One-way communication, nodes act only as sensors and hence the data flow is from nodes to sink(s) ; Wireless backbone, usually in environmental monitoring no wired connections are available to connect sink(s) to the fixed network. Significantly different are the requirements of a typical industrial application where wireless nodes are used for cable replacement: reliability, communication must be robust to failure and interference; Security, communication must be robust to intentional attacks; Interoperability, standards are required; High data rate, the process to be monitored usually carries a large amount of data; Two-way communication, in industrial applications nodes typically act also as actuators and hence the communication between sink(s) and nodes must be guaranteed; Wired backbone, sinks can be connected directly to the fixed network using wired connections.

As an example, a self-organizing singlesink WSN, enabling environmental monitoring through the estimate of a scalar field over a bidimensional scenario, is considered. Nodes are assumed to be distributed according to a Poisson point process (PPP) over the area and are organized in a clusterbased topology. Connectivity issues, randomness of the channel, MAC issues and the role of distributed digital signal processing (DDSP) techniques are jointly accounted for, in a mathematical framework developed in the paper. Owing to the requirement of low device complexity together with low energy consumption (i.e., long network lifetime), a proper balance between communication and signal processing capabilities must be found. The model developed allows the analysis of the network under two different perspectives: the estimation of the process and the energy consumption. The tradeoff between energy conservation and estimation error is discussed and a design criterion proposed. As an example result, the required node density is found as a tradeoff between estimation quality and network lifetime for different system parameters and scalar field characteristics. It is shown that both the DDSP technique and the MAC protocol choice have a relevant impact on the performance of a WSN.

III. RESULTS

In this section a lowcost hardware and software WSN testbed developed for agricultural monitoring is described. The platform has been designed to provide the farmer with a periodic and punctual monitoring of physical parameters (e.g., temperature, air pressure, humidity) for a real-time control of different microclimates in cultivation. Thanks to this information it is possible to increase the quality and amount of production, cut costs, and reduce the pollution caused by weedkillers. The testbed developed. Each node is composed of an IEEE 802.15.4 radio transceiver based on Chipcon CC2430 operating in the 2.4 GHz band, photovoltaic panels, rechargeable batteries, and temperature and humidity sensors. Each node emits a maximum power equal to 0 dBm and it is capable of communicating with neighbor nodes up to a maximum distance of 100 meters in line of sight conditions. The communication protocol has been designed to allow an extremely low duty cycle where nodes wake up for 10 seconds (activity mode) at intervals of 15 minutes. During the activity mode, each node collects measured data from its sensors and transmits the information to the sink node. In case the sink node is out of the radio link range, data are forwarded by intermediate nodes, which act as relays, in a multihop fashion according to a mesh network topology. To this purpose, a robust ad hoc network synchronization protocol has been designed to compensate relative clock drifts among nodes thus avoiding that nodes wake up in not overlapped time intervals. In sleeping mode, node consumption is only 0.5 mA, whereas during the activity mode the overall consumption is 30 mA. The resulting network lifetime is in the order of several weeks (in the absence of photovoltaic panels) and it is limited only by the rechargeable battery lifetime when photovoltaic panels are present. All sensed data collected by the sink node (coordinator) are then forwarded to the Internet every 2 hours through a GPRS link. The periodic report as well as each node status can be examined through a remote standard Internet connection.

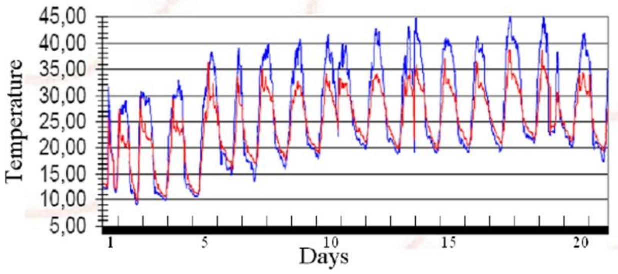

Fig.3

Here Screenshots of temperature behavior measured by 2 different nodes (red and blue curves, respectively) (Fig.3) and The behavior of the battery charge in Volt by passing time, expressed in hours, when photovoltaic panels are used.(Fig.4).

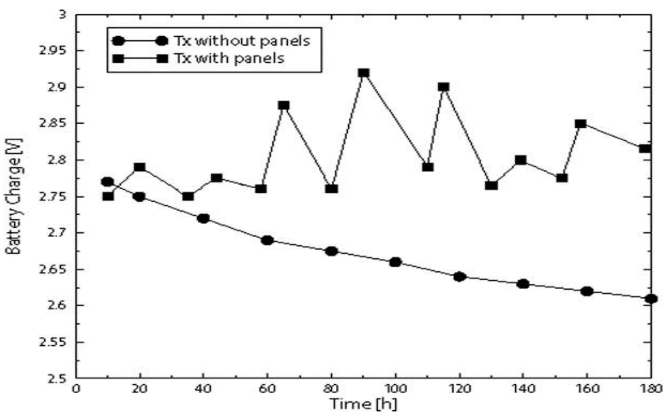

Fig.4

The 802.15.4 physical layer operates in three different unlicensed bands (and with different modalities) according to the geographical area where the system is deployed. However, spread spectrum techniques are wherever mandatory to reduce the interference level in shared unlicensed bands. (Fig.5)

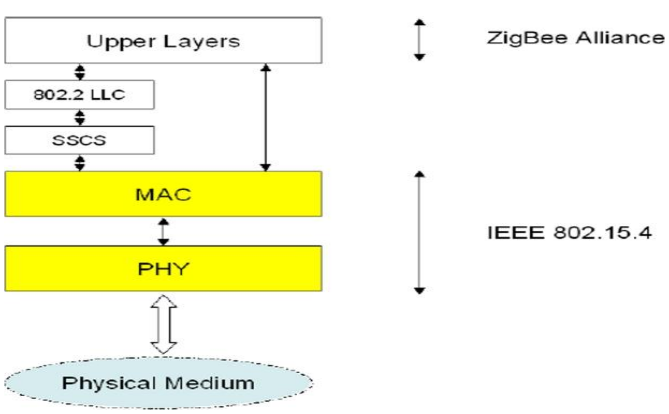

Fig.5

To overcome the limited transmission range, multihop selforganizing network topologies are required. These can be realized taking into account that IEEE 802.15.4 defines two types of devices: the Full Function Device (FFD) and the Reduced Function Device (RFD). The FFD contains the complete set of MAC services and can operate as either a PAN coordinator or as a simple network device. The RFD contains a reduced set of MAC services and can operate only as a network device. Two basic topologies are allowed, but not completely described by the standard since definition of higher layers functionalities are out of the scope of 802.15.4: the star topology, formed around an FFD acting as a PAN coordinator, which is the only node allowed to form links with more than one device, and the peertopeer topology, where each device is able to form multiple direct links to other devices so that redundant paths are available. Here screenshot of the two IEEE 802.15.4compliant network topologies: star and peertopeer topology. (Fig6).

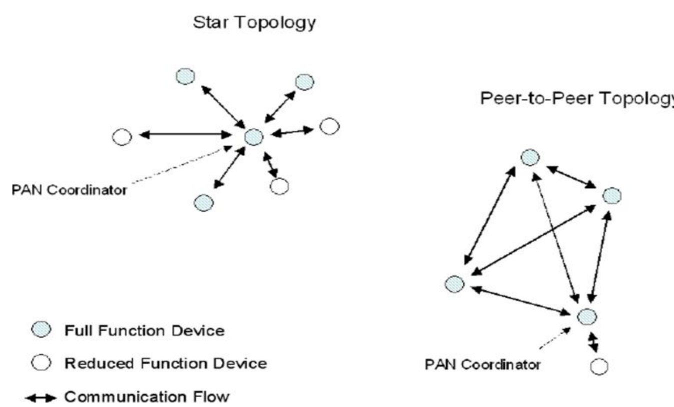

Fig.6

Zigbee defines the network and application layers above the 802.15.4. Zigbee is being promoted by the Zigbee Alliance and its main contribution is giving mesh network capabilities to 802.15.4 applications. Mesh networking allows reconfiguration around blocked paths by hopping from node to node until the data reaches the destination. Moreover, Zigbee specifications define a beacon enabled tree based topology, as a particular case of the IEEE 802.15.4 peer to peer networks. Here screenshots of Zigbee compliant tree network topology. (Fig.7)

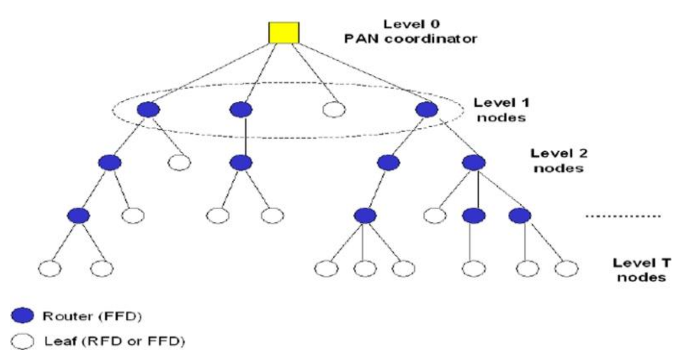

Fig.7

Also the screenshots of the tracking of the beacon's parent, performed by a generic child as stated above, nodes must be in beacon enabled mode: each child node tracks the beacon of its parent where the tracking period is outlined as a dashed rectangle. A core concept of this tree topology is that the child node may transmit its own beacon at a predefined offset with respect to the beginning of its parent beacon: the offset must always be larger than the parent superframe duration and smaller than beacon interval. This implies that the beacon and the active part of child superframe reside in the inactive period of the parent superframe. (Fig.8)

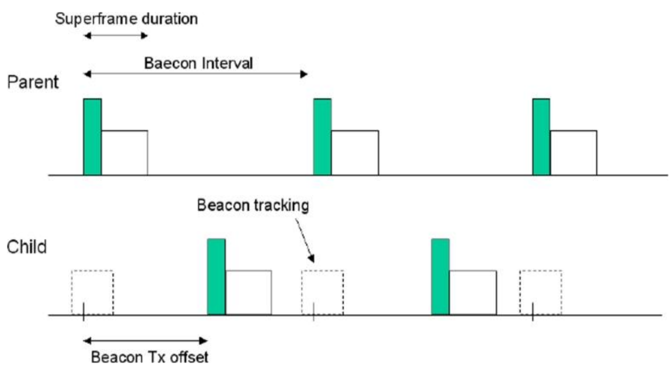

Fig.8

The mean energy spent by an 802.15.4 node working in non-Beacon enabled mode, belonging to a network of *N* nodes organized in a star topology. (Fig.9)

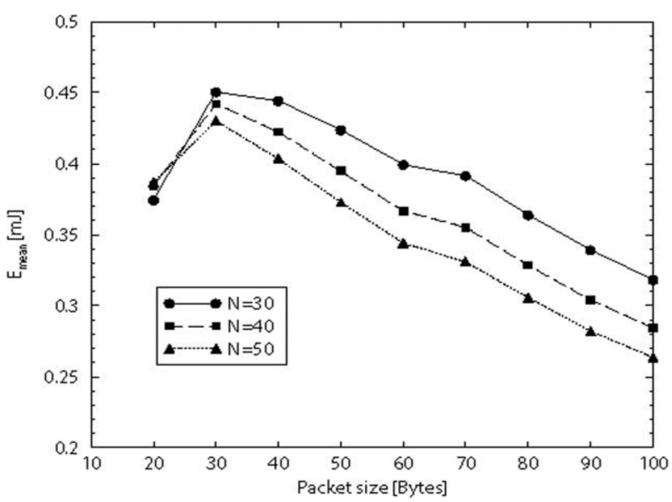

Fig.9

IV. CONCLUSIONS

The aim of this paper is to discuss some of the most relevant issues of WSNs, from the application, design and technology viewpoints. For designing a WSN, in fact, we need to define the most suitable technology to be used and the communication protocols to be implemented (topology, signal processing strategies, etc.). These choices depend on different factors, above all the application requirements. The first part of the paper is devoted to the discussion on the constraints that must be satisfied by the WSN and the different aspects that must be taken into consideration in the design of a WSN. The second part, instead, is related to the actual possible choices that could be done, in terms of technologies. The aim is to help the designer in the choice of the most suitable technology. The attention is mainly focused on the IEEE 802.15.4 standard, for which also some potential performance levels are provided. Finally, the paper provides a vision on future trends of the shortand longterm research on WSNs for future research when the functionality is added. This research started out with a couple of goals in mind that were centered on the necessary management tools.

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