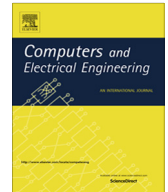




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Bluetooth for Internet of Things: A fuzzy approach to improve power management in smart homes [☆]

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ABSTRACT

Thanks to the introduction of the Internet of Things (IoT), the research and the implementation of home automation are getting more popular because the IoT holds promise for making homes smarter through wireless technologies. There is a main requirement that make a wireless protocol ideal for use in the IoT, that is the energy efficiency. Bluetooth Low Energy (BLE) has a high potential in becoming an important technology for the IoT in low power, low cost, small devices. However, specific techniques can be used in such a way as to further reduce the energy consumption of BLE. To this end, this paper proposes a fuzzy logic based mechanism that determine the sleeping time of field devices in a home automation environment based on BLE. The proposed FLC determines the sleeping time of field devices according to the battery level and to the ratio of Throughput to Workload (Th/Wl). Simulation results reveal that using the proposed approach the device lifetime is increased by 30% with respect to the use of fixed sleeping time.

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1. Introduction

With the increasingly rapid development of various communication technologies, more and more devices are able to access the internet and to interact with it. When considering a global network of smart objects of all kinds, such as computers, appliances, clothes, sensors, interacting with each other through Internet protocols, the reference scenario is called Internet of Things (IoT). The devices that are part of the network of objects are called “smart objects” or “smart things”, that unlike normal devices are able to interact within the communication system in which they are inserted since they have an active role. The devices can be identified by the following characteristics:

- They are the real objects characterized by cost, shape, weight, etc.
- They have limited resources in terms of processing capacity, memory, energy supply and routing [1].
- They may be influenced and influence the surrounding environment by acting as actuators [2].

Thanks to the developments of wireless technologies and to studies about IoT, the “anywhere, any-time by anything” communication is no longer considered a true utopia. In fact, more and more devices, at any-time, even without receiving a physical input, can access the network and interact with the other connected devices [3]. The practical significance of

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the IoT is made possible through enabling technologies such as Wireless Sensor Networks (WSNs), mainly used for sensing operations. The nodes of a WSN are sensors arranged within an environment, with the aim to detect certain data that are sent to one central node in order to process them.

With the introduction of the IoT, the research and the implementation of home automation are getting more popular [4]. In fact, built on connections between digital devices and nearly anything that can be monitored or controlled electronically, the IoT holds promise for making homes smarter. Home Automation (HA) refers to the mechanization and automatic control of various residential activities. Typically, HA provides a centralized control of electrical appliances, such as air conditioners, lighting and security systems and even the home theater. Adding intelligence to home environment it would be possible to obtain excellent levels of comfort, and another feature taken into account is the energy savings. Moreover, the integration of several electrical devices in the household is an open challenge because of the absence of a cheap and standardized communication protocol between them [5]. Anyhow, at present, a wireless network exists in almost all homes. Smart-phones and tablets are natural devices to enable the control of electrical ones. In such a situation, the wireless protocols become an easy avenue for self-installation of HA systems. Moreover, a smart home has to meet several requirements such as:

- Safety, i.e. the protection from possible malfunctions.
- Security, i.e. authentication, authorization and data protection.
- Energy saving, i.e. a smart mechanism to reduce power consumption.

Several wireless technologies, such as Bluetooth Low Energy (BLE) [6], IEEE 802.15.4/ZigBee [7] and IEEE 802.11/Wi-Fi [8], that can support the remote data transfer, the sensing and the control, have been proposed in order to embed various levels of intelligence for smart home. BLE is being adopted by the health care industry for portable medical and lifestyle devices. On the other hand, the battle between ZigBee and low-power Wi-Fi technologies for home control and automation has just begun. The manufacturers of wireless devices are urgently looking for new revenue streams, and machine-to-machine communication and location-based services seem to be good places to make a bet. Both can use existing infrastructure and are very much a part of the emerging IoT market.

Anyhow, there is a main requirement that make a wireless protocol ideal for use in the IoT, that is the energy efficiency. In many cases, the sensing nodes are battery-powered, so a low-power feature is a basic requirement. In the design of devices that implement a wireless protocol several mechanism can be adopted in order to reduce the power consumption, including low-leakage process technologies, best-in-class low-power non-volatile memory/flash memory technologies, architectural innovations and various clocking schemes. For battery-powered nodes, all of those techniques are needed in order to achieve the lowest possible power consumption.

To cope with this problem, this paper proposes a fuzzy logic based mechanism in a home automation environment. The core of the proposed architecture is represented by a wireless network, organized in Wireless Automation Cells (WACs), based on Bluetooth Low Energy Protocol and managed by a Master node. The Bluetooth Low Energy protocol has been chosen from the results of an analysis carried out in the Section 2.2 of this paper. In each WAC there is a fuzzy module that aims at the energy saving of the network. In fact, the goal is to improve the low energy consumption of BLE through a fuzzy logic controller.

The paper is organized as follows. Section 2 deals with the BLE support for IoT in home automation environments, while Section 3 shows main related works in order to deduce the innovations introduced with this work. Section 4 describes the system architecture and the proposed approach, showing the fuzzy logic controller module. Section 5 shows the performance obtained by the proposed approach and finally Section 6 concludes the paper and outlines some hints for future work.

2. Bluetooth Low Energy support for IoT in home automation

In this section an analysis of wireless communication suitable for energy management in home automation applications is presented. In recent years, wireless communication technology has seen sudden growth and several approaches are also capable to support the energy management through widespread environmental sensing. This has been possible through the advancements of low-power and low-cost radio frequency wireless communication technologies, with smaller form factor, greater sensing density and longer functionalities lifetime.

In the IEEE 802.11/Wi-Fi family, the nodes compete for the medium access according to the Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) protocol. However, contention-based approaches are not able to guarantee an upper bound on the medium access delay, so they are not adequate for time-constrained traffic and for applications that require low power consumption. In fact, Wi-Fi does not possess intrinsically ubiquitous characteristics, but the explosion of laptops and mobile devices has driven widespread adoption. However, in the field of energy management this adoption seems unlikely. In fact, the native design of Wi-Fi does not have the energy management in mind and for many applications, particularly environmental sensing, the IEEE 802.11 is considered too power hungry and in some cases the components are still too large. For this reason, other approaches have been developed.

ZigBee, a pure wireless technology, is based upon the IEEE 802.15.4 standard for WPANs (Wireless Personal Area Networks). It is intended to be a low-cost, low-power wireless mesh network standard allowing for secure communication with a data rate of up to 250 kbps. ZigBee was originally conceived as an alternative to Wi-Fi/Bluetooth Classic around 1998 as a

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