APPLICATIONS FOR IEEE 802.15.4 STANDARD UTILIZING THE ZIGBEE NETWORK PROTOCOL

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Abstract. *The IEEE 802.15.4 is a wireless standard that can be used in several segments, such as residential, commercial or industrial area. From this IEEE standard it was developed the Zigbee protocol, which has been used in several areas, among them, medical, industrial control and home automation, and vehicle identification. This paper aims to present an overview of these applications, demonstrating the applicability of wireless sensor technology, with low cost, and low power consumption.*

Keywords: Wireless Networking, Wireless Sensors, Sensor Networks.

1. Introduction

In the last decade technologies of wireless networks are progressing and becoming common in our lives, whether in both industry and households [3], [9], [10], [11]. The great expansion of wireless networks was largely determined by their user friendly features, convenience and mobility [1], [9].

This technology allows the transmission of data through radio frequency and can be used in situations when, for example: one cannot install a fixed network (wired); to create a temporary network infrastructure, when one wants to extend a network and gives a new dimension to the existing applications [2], [9]; or for automation and control of industries and households [3], [9], [10], [11], [12], [13].

This paper presents some applications of Zigbee, a protocol for wireless networks based on IEEE 802.15.4, which is low cost and implementation [2] and is applied to the standard personal wireless networks, known as WPAN (Wireless Personal Area Network) in different segments.

2. Wireless Networking

Wireless networks are classified according to their coverage area, frequency and transmission rate: (i) WPAN are personal networks, such as Bluetooth network of a cell phone that connects to another device that has the same technology; (ii) WLAN (Wireless Local Area Network) are local networks, such as a WiFi network in a hotel; and (iii) WMAN (Wireless Metropolitan Area Network) are metropolitan networks that can provide services to a city like WiMAX networks.

Table 1 shows some standards to use the technology of wireless networks with their respective data rate, range and transmission rate.

As specified in Table I, the WPAN comprises the IEEE standard 802.15.1, 802.15.3, 802.15.3a, and 802.15.14 (Zigbee). In the case of WLAN, it involves the IEEE standards 802.11a, 802.11b,

802.11g and 802.11i, where difference between last three is the transmission rate. Finally, the standards IEEE 802.16 (WiMAX) and 802.16e are for WMAN.

TABLE I
ESTABLISHED STANDARDS FOR THE USE OF WIRELESS NETWORKS [2]

Padrão IEEE	Freqüência	Alcance	Taxa
802.15.1 (Bluetooth)	2.4GHz	<10m	723 Kbps
802.15.3 (UWB)	2.4GHz	30-50m	10-55Mbps
802.15.3a	3.1-10.6 GHz	<10m	110-480Mbps
802.15.4 (Zig Bee)	868 MHz, 915MHz, 2.4 GHz	10-75m	20-250Kbps
802.11a	5GHz	< 50m	6-54Mbps
802.11b	2.4GHz	<100m	2-11Mbps
802.11g	2.4GHz	<100m	20-54Mbps
802.11i	2.4GHz	<100m	20-54Mbps
802.16 (WiMAX)	10-66GHz	≈10km	60-100Mbps
802.16e	2-6GHz	≈10km	70 Mbps

Figure 1 shows the classification of wireless networks according to the coverage area of each.

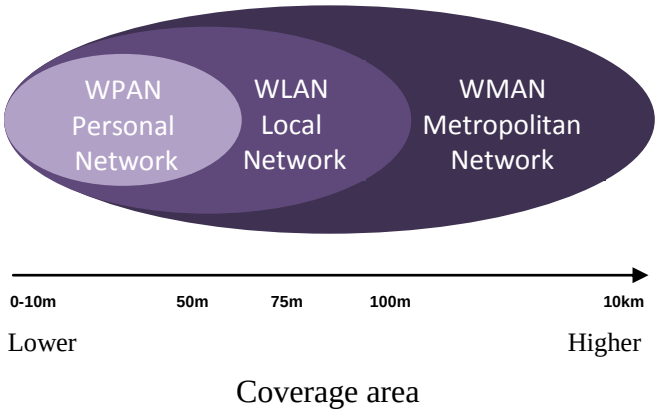

Figure 1 –Classification of wireless networks according to coverage area [2].

The advantages of a wireless network are [Santana *et al.*, 2004]:

1) Ease installation: without demanding any prior structure, wireless networks can be installed easily and quickly. In the case of structured networks, is sufficient to install an Access Point (AP), which is connected to a wired local network or the Internet. Computers can be added subsequently as needed.

2) Mobility: in a certain range, the devices can change position at any time. This allows information, computing resources and applications can be accessed by clients that are not fixed or in pre-determined locations.

3) Cost Reduction: due to the mobility factor, it is decreased the costs of installation and maintenance of networks, especially when considering the cost of installing wired networks in locations that require civil work, thereby reducing the cost of infrastructure.

The disadvantages of a wireless network can be listed as:

1) Minor Band Transmission: wireless networks, in general, provide links with lower bandwidth. Wired Ethernet LANs, for instance, reach baud rate of the order of tens of Gbps, while local wireless networks typically operate up to tens of Mbps [2], [14], except for 802.11ac and 802.11ad, latest technologies, that can transmit at rates up to 6.7 Gbps [16].

2) Error Rates: wireless networks present a bit error rate (BER - Bit Error Rate) superior to wired networks. For example, in a fiber optic link BER varies between 10^{-8} and 10^{-9}. On the other hand, on a wireless link, the bit error rate decreases within the range of 10^{-4} to 10^{-6} [2], [14], [15].

3) Addressing: the logical address of a station on a wired network is usually tied to the address of the network to which the station is connected [14]. In the context of wireless networks, because of the mobility of the stations, their addresses cannot depend on your geographic location [2], [14].

4) Routing: In the context of wireless networks, stations are moved from one side to the other of non-deterministic way, creating a dynamic topology, which directly impact not only in addressing but also in algorithms and routing protocols.

5) Devices with Limited Computational Power: The prospect for a mobile computing environment is many devices used in this environment will always be scarce and computationally simplified, compared to other devices, however, they are able to perform minimum applications. These limits are important in the development of any application for these environments characteristics, featuring a user profile classified as a user of scarce resources (thin user).

The modes of operation of wireless networks enable the creation of dynamic topologies, and, due to the fact that they support different modes of operation, they can be either infrastructured or ad-hoc [2], [14].

2.1 Infrastructured Networks

Infrastructured networks are those in which all communication is via an access point, similar to the functioning of cellular telephony, where all communication passes through a central point. Typically, this point is connected to a wired network with increased throughput and allows sharing of network resources [14].

2.2 Peer-to-Peer Networks

Peer-to-peer or ad-hoc networks consist of networks where there is no central administration to exchange of information. This type of arrangement is formed by several mobile nodes that are capable of exchanging information with each other [14].

3. Standard Zigbee

The Zigbee is a wireless technology used in various research and commercial applications. Based on the specification of IEEE 802.15.4 standard [3], this open model has excellent wireless connectivity, low-cost applications and low power consumption [4]. The main applications of this protocol involve the automation and control of residential and business buildings, [9], [10], [11], [12], [13], electronic devices and computer peripherals and medical monitoring [7], [8].

As defined by the IEEE [5], one can identify two basic types of devices in a ZigBee network: the Full Function Device (FFD) can operate in the entire topology, working as a coordinator, and, therefore, has a more complex construction; and the Reduced Function Device (RFD), with a simpler construction, it is limited to a star topology and can only communicate with devices FFD.

The FFD has the functionality adjusting network parameters, the transmission of information over the network, the management of the nodes, storing the information of the nodes and the distribution of messages; and always remain in the activated or "active" state. Devices of RFD type have passive role in the network, perform searches for available networks, make the transfer of application data, determine the status of data and request data from the network coordinator, and can remain in the sleeping state or "sleep" for long periods of time [5].

From these devices, it is possible to have in a Zigbee network three logical classes: coordinator, router and end point, the first two being implemented in FFD physical devices, and the latest can be applied in both FFD and RFD physical devices. Figure 2 shows the possible topologies that can be used from the aforementioned physical devices and logical classes.

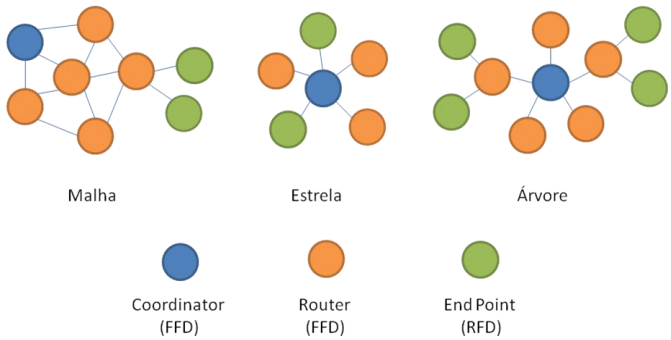

Figure 2 – Topologies that can be formed from RFD and FFD physical devices and Coordinator, Router, and End Point logical classes [5].

As can be seen in Figure 2, the possible computer network topologies that can be formed from RFD and FFD physical devices are mesh, star and tree [5]. All topologies require a coordinator node, which is responsible for managing the other network nodes. This node is also responsible for coordinating the input and output of new nodes in the Zigbee network.

4. Applications Utilizing Zigbee Protocol

The Zigbee protocol has a wide area of actuation. In this chapter some possible uses of this protocol for the medical, residential and vehicular areas will be exposed.

4.1 Zigbee Protocol Applied to Vehicle Identification

The vehicle identification is becoming very common in the cities, for the collection of parking or road use services such as toll collection. The convenience provided by this application brings more enthusiasts, whether customers who have an identification device in their vehicles, or companies that offer such a facility, through radio frequency receivers for clients.

Figure 3, for example, one can see a type of label (tag) carrier activated by a radio frequency (RF) which is securely installed in the vehicle to be identified, authenticated and managed. Each vehicular RF tag is programmed to have a unique serial number to identify it, and a password to authenticate the driver. An RF tag reader is installed near the entrance of the establishment. When a vehicle stops at the entrance, the reader detects the RF tag on the vehicle and retrieves

the same authentication information. This information is transferred to a central database to check whether access can be granted to the vehicle that is entering the particular location. Using the information received from the base station, a personal security located in entrance, or automated security system, takes measures to allow or deny entry of the vehicle for installation [6].

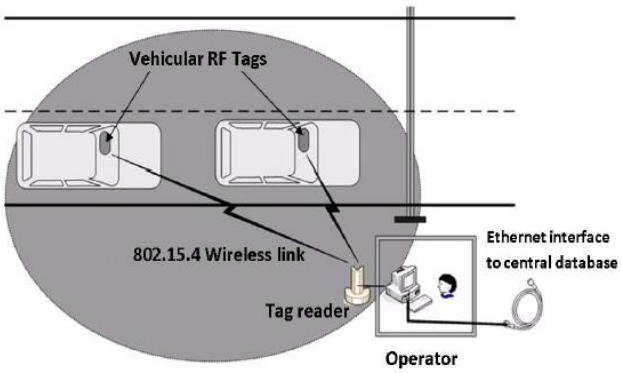

Figure 3 – Vehicular identification system using the 802.15.4 standard [6].

4.2 Medical Applications for Zigbee Protocol

Wireless sensor networks present data in real time and, therefore, have great potential in medical care. With the continuous development of modern society, the traditional model of running hospitals failed to meet public needs [7]. The application of Zigbee in medical applications reduces the workload of hospitals, and the doctors remotely can monitor patients through the network, and provide, in real time, a diagnosis or an advise to their patients. Such devices can also: compare data in real time with pre-defined values by the physician, and generate an alert when certain values are reached [7].

Additionally, the use of this communication technology can provide real-time detection of physiological parameters such as blood pressure, oxygen saturation, and even generate an electrocardiogram without changing the normal routine of a user [8].

4.3 Zigbee Protocol Applied to Home Automation

The automation of household devices enables a variety of services that can bring greater comfort to the occupants of a residence [10], [11], [12], [13].

Through the Zigbee protocol it is possible to monitor and control multiple devices in a residence. For example, one can connect a lamp or adjust the temperature of an air conditioner of home before leaving work. This would be accomplished through a central control hosted on a server that communicates with all Zigbee devices of the environment and provides control online form. Therefore, the user would have a lot of control over his home, while outside it [10], [11], [12], [13].

A proposal for this type of solution is presented in [9], in which multiple devices communicate with a Zigbee coordinator via RF, which, in turn, is connected to the server. The server then exchanges information with devices and provides an interface that can be accessed from the local network or over the internet.

Figure 4 shows a network topology to monitor and control the devices via the Internet, from anywhere in the world.

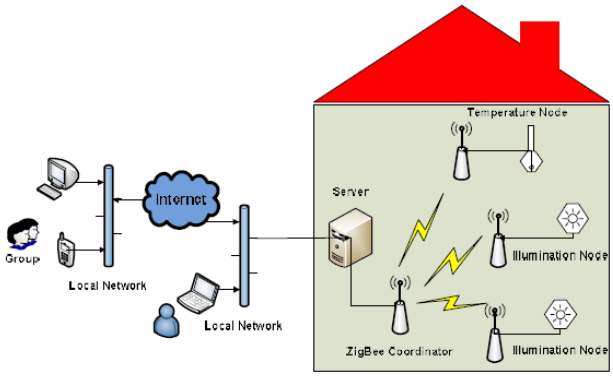

Figure 4 – Proposal of a residential automation using Zigbee [9].

In Figure 4 it is also possible to see the presence of two communication nodes for lighting and one communication node for temperature control, and these nodes are communicating with a Zigbee coordinator, transmitting data via local network or over the Internet.

5. Conclusion

The present work shows where the IEEE 802.15.4 standard is inserted in the context of wireless networks, which provided, in general, to ease our lives. From work undertaken with the IEEE 802.15.4 standard, we expose some applications; however, there are several other ways of using the Zigbee protocol. Although only three applications were exemplified, it is possible to guess that this wireless technology, with low cost and low power consumption, has a great potential for other applications, such as in agronomy, monitoring different variables in greenhouses.

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