Wireless Sensor Networks: A Low-Power, Wireless-Enabled Application

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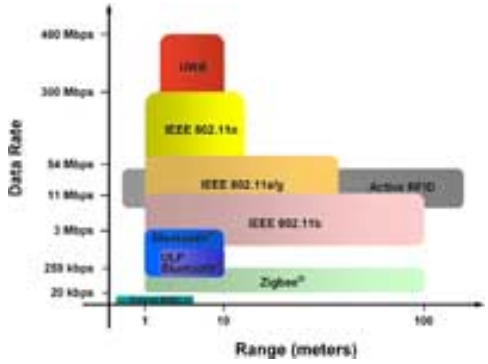
The explosion of wireless technologies in recent years has allowed the emergence of several wireless standards in the industrial scientific and medical (ISM) band. With these new standards we are experiencing penetration of wireless applications in every segment of our daily lives. No doubt that wireless sensor network (WSN) is an important application that has benefited the most from the proliferation of these standards.

Imagine a farmer in the American Midwest facing the challenges of monitoring the temperatures of a thousand head of cattle daily in order to prevent such animal illnesses as foot and mouth disease that can decimate his herd. With wireless technology, these challenges can be easily overcome by attaching a temperature sensor equipped with a wireless transmitter on each cow, transmitting its reading to a main terminal. This simple example of a WSN shows how using wireless technology can help save time and cost. This article presents an overview of the ISM band and WSN, as well as the wireless standards that support them.

Industrial Scientific and Medical Band Overview

The ISM band is part of the frequency spectrum that can be used by anyone without a license. The only requirement for developing products in the ISM band is compliance with rules governing this part of the frequency spectrum. These rules vary from country to country. In the United States the Federal Communication Commission (FCC) defines these rules, whereas in Europe the European Telecommunications Systems Institute (ETSI) is the governing body. FCC Regulations Part 15 defines the band requirements in the US. Table 1 identifies the various frequencies and bands, and lists the corresponding governing bodies.



[1]

The 2.4 GHz bands and several sub-1 GHz bands are the most widely used ISM space today. Due to so extensive clutter in the 2.4 GHz bands, some activities are moving into the 5 GHz band – but remain very limited because of achievable range concerns. While the 2.4 GHz is universal, the sub-1 GHz bands allocated to the low-power wireless application vary from country-to-country. In the US, the most popular band remaining is 902-928 MHz, whereas in Europe most activities are in the 868 MHz range.

The 2.4 GHz band is recommended when it is necessary to interoperate with other systems, as well as when operating in different geographical spaces is a key concern. The main disadvantage of using 2.4 GHz band is mostly an overcrowded space, as well the limited range, due to poor propagation characteristics of the 2.4 GHz frequency.

Choosing to design in the sub-1 GHz band can help solve some of the issues faced in the 2.4 GHz band; however, the sub-1 GHz band has its own limitations:

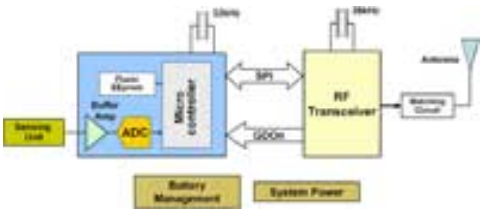
a. Restricted duty cycle

b. Impossible to achieve interoperability with other systems

c. Geographical operation limitations (ex: a wireless meter designed in the 902-928 MHz band for the US will not operate in Europe.)

Depending on the frequency, the target data rate, the distance, and the desired level of interoperability, several standards operating in the ISM space have emerged. Figure 1 shows the most relevant standards available to the wireless engineer for developing products.

Wireless Sensor Networks Overview

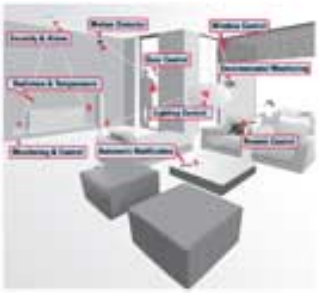


[2]

It is clear that ‘smart’ environments represent the next evolutionary development step for building, utilities, industrial, home, transportation, and agriculture. Thus, the interest in WSN is steadily growing. A WSN consists of a number of sensors spread across a geographical area.

A WSN generally consists of a host or “gateway” that communicates with a number of wireless sensors via a radio link. Data is collected at the wireless sensor node, compressed, and transmitted to the gateway directly or, if required, uses other wireless sensor nodes to forward data to the gateway. The gateway then ensures that the data is input into the system.

Each wireless sensor is considered a node and presents wireless communication capability, along with a certain level of intelligence for signal processing and networking data. Depending on the type of application, each node can have a specific address. Figure 2 represents a generic block diagram of a node. It usually comprises a sensing unit, a microcontroller to process data, and a RF block for the wireless connection. Depending on the network definition, the RF block can function as a simple transmitter or transceiver (TX/RX). When designing the nodes, it is very important to pay attention to the current consumption as well as the processing capability. The microcontroller’s memory is very dependent of the software stack used.



[3]

Figure 3 shows a WSN being applied in a home environment. In this network we can observe different types of sensors such as motion detectors, radiators, temperature monitoring, etc.

WSN targets four main goals:

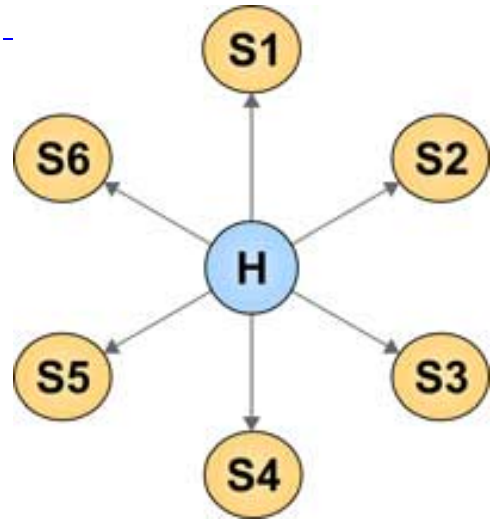
1) Reading the value of some parameters at a given location and transmitting it to the main processing center. In agricultural environments such as the herd of cattle mentioned earlier, reading the temperature of each cow helps to determine which cow needs closer monitoring.

2) Monitoring the occurrence of certain events such as in a medical application where the peak of the blood pressure and pulse, along with the heart rate, are monitored.

3) Tracking movement of specific objects is widely used in the military to track enemy vehicles.

4) Help classify detected objects, especially in the traffic control environment.

Two main topologies are used in the WSN:



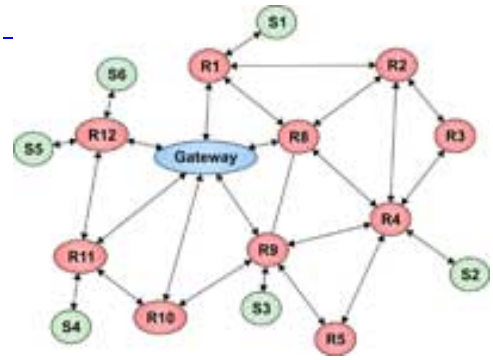
[4]

A) Star network: As illustrated in Figure 4, a star network consists of a point-to-multipoint wireless connection where a single host is connected to several nodes in a bidirectional or unidirectional manner. This type of topology can be very interesting, if low-power consumption and low-software overhead are key parameters. Its limitation might be the achieved range, as each node should be within range of the host. Several standards can be used to achieve this kind of topology. Bluetooth®, IEEE 802.15.4 or proprietary systems are most widely used. Note that the Bluetooth platforms have not met wide acceptance due to some Bluetooth protocol limitations.

B) Mesh network: In a mesh network topology, as described in Figure 5, nodes are

connected with many redundant interconnections. Should a node fail, there are many other ways for two nodes to communicate. This topology provides good reliability, but could be very costly in terms of current consumption and software. This topology can be achieved either by a proprietary or Zigbee® standard.

Conclusion



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There is no doubt that WSN is gaining more traction every day, which comes along with more emerging standards. However, it is very important to notice that most of these standards have not yet reached a maturity level. Rather, they are all still in the infancy phase. A scrupulous WSN design engineer will want to do a thorough study of his network needs in terms of architecture, as well as the ability of a particular standard, to satisfy his key requirements for current consumption, maximum allowed number of nodes, battery life, data rate, and operating frequency. It is these vital elements that guide the decision for choosing a standard.

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