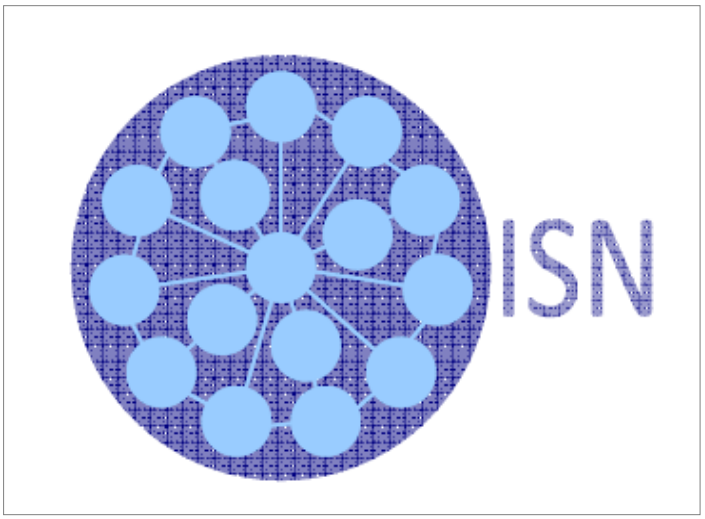

DESIGN APPROACH FOR CO-EXISTENCE

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Contents

1. Purpose

This document contains the studies of different wireless protocols and the evaluation approaches to co-existence of these wireless protocols. In this case, we will focus in the IEEE 802.15.4 standard and Low Power Wifi in the ISN wireless nodes. The ISN project belongs to the Information Technology for European Advancement (ITEA) 2 [1] framework.

2. Introduction

The coexistence of 2.4 GHz wireless devices operating in one place has become a problem. With low transmit power, the widely deployed IEEE 802.15.4-based networks are easily interfered with by other 2.4 GHz wireless networks, such as IEEE 802.11. IEEE 802.15.4-based wireless networks have paid great attention to the coexistence between themselves and with other non-IEEE 802.15.4 wireless networks. This problem has been further promoted by two new industry wireless standards, WirelessHART and 6LowPAN, to meet special industry requirements. This document surveys the studies on the coexistence between IEEE 802.11 and IEEE 802.15.4

3. Solutions of Coexistence

Solutions are performed permanently to mitigate the interference. Most of solutions have been included into IEEE 802.15.4-based network standards and perform independently of interference.

The follow table list inherent solutions of different IEEE 802.15.4 based networks standards. The second column is a simple description of the solutions. The third column is the basic principle of interference mitigation. The essence of coexistence problem is the conflict of spectrum resource, so the basic principle for interference mitigation is to avoid collision by three kinds of resource sharing (frequency, time, and space).

Source	Solution	Sharing Resource
IEEE802.15.4	DSSS	Frequency
	Multiple Channels (FDMA)	Frequency
	CSMA	Time
	TDMA	Time
	High data rate for low rate application	Time
	Short packet length	Time
ZigBee	Channel scan before network forms	Frequency
	Mesh networking and path sharing	Space
	Network layer frequency agility	Frequency
WirelessHART	Channel hopping	Frequency
	Black list	Frequency
6LowPAN	Select the most appropiate channels	Frequency

Figure 1: Coexistence solutions

4. Solution in IEEE 802.15.4

The basic idea of spread spectrum is to transmit the signal over additional bandwidth, using more frequencies but less power per frequency. One of most used spread spectrum is direct sequence spread spectrum (DSSS), which is used to promote coexistence of IEEE 802.15.4. DSSS makes use of a pseudorandom code sequence, often called a "chipping sequence," which is transmitted at a maximum rate called the chip rate. The chipping sequence is used to directly modulate the basic carrier signal and to encode the data being transmitted.

In addition to DSSS, IEEE 802.15.4 increases the opportunities for coexistence by employing a technique, generally known as frequency division multiple access (FDMA), which divides the 2.4 GHz ISM band into 16 nonoverlapping channels, which are 5 MHz apart. At least two of these channels, specifically 15 and 20, fall between the often used and nonoverlapping 802.11 channels 1, 6, and 11 as Figure 2.

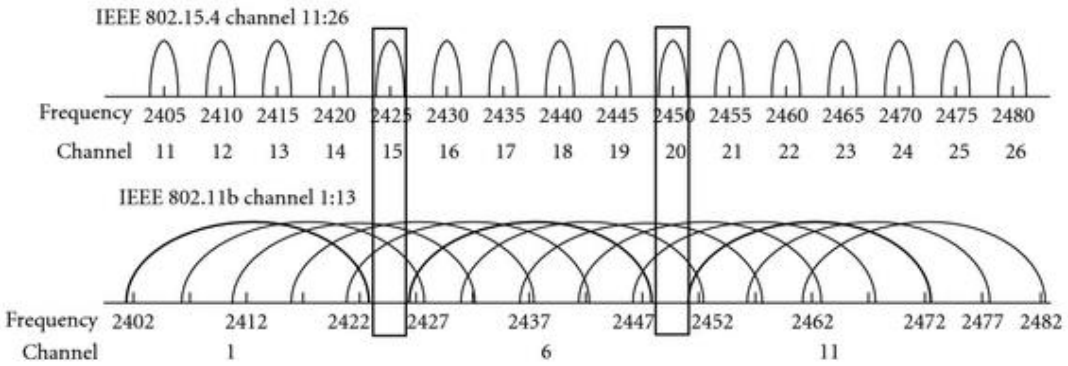

Figure 2: Channel assignment in 2,4 GHz band.

Even with the techniques described above in place, an IEEE 802.15.4 device may find itself sharing a channel with interferers. There are a number of ways to solve this problem, and the approach taken by the IEEE in the 802.15.4 standard is known as carrier sense multiple access with collision avoidance (CSMA/CA). A similar technique, carrier sense multiple access with collision detect (CSMA/CD), which has been used successfully for years in Ethernet, has the virtue that it requires no synchronization between devices. Instead, it employs a simple "listen before you talk" strategy.

In addition to CSMA, IEEE 802.15.4 also supports time division multiple access (TDMA) to control access to the network. TDMA is a widely used MAC technique that provides collision-free, deterministic communications. TDMA uses time slots where communications between devices occur. A series of time slots form a TDMA superframe. Superframes are repeated continuously. Typically, two devices are assigned to a given slot. One is designed as the source, and the other is the destination.

Most of the intended applications for IEEE 802.15.4 devices require a very low data rate; however, IEEE 802.15.4 chooses a relatively high data rate, 250 Kbps, because a radio with high data rate occupies the channel far less and leaves lower chances for collision.

Using a shorter packet length can generally reduce the packet loss. The IEEE 802.15.4 specifies the maximum number of bytes that can be transmitted in the MAC data payload as 102 bytes.

5. Solution in ZigBee

The ZigBee protocol standard [2], which is built on top of IEEE 802.15.4, provides additional benefits of a well-developed wireless networking standard that is designed, built, and supported by hundreds of the world's leading technology companies. Most of these companies have thoroughly and independently investigated the coexistence capability of ZigBee and IEEE 802.15.4. ZigBee Alliance in [2] introduces coexistence techniques. There are also numerous technical reports of coexistence from ZigBee member companies [4–7].

When a ZigBee network is created, the ZigBee coordinator is required to scan the list of available channels and automatically select the channel with least interference.

Mesh network can provide path sharing and dynamic routing to improve coexistence.

ZigBee devices use the scanning facilities in IEEE 802.15.4 to detect interference and report the detection result to the ZigBee coordinator. The coordinator may direct the network to leave the channel it is currently using and turn to another one.

6. Solution in WirelessHART

WirelessHART is an open wireless communication standard specifically designed for process measurement and control applications. Like ZigBee, physical layer and parts of MAC layer in WirelessHART are based on IEEE 802.15.4, considering that industry circumstances have high demands on robustness, coexistence, power consumption, security, and so on, WirelessHART is an enhanced version of ZigBee. Many new technologies are introduced into WirelessHART, such as frequency sharing, path sharing, and blacklist. Most of these technologies relate to improving the coexistence capability.

WirelessHART introduces channel hopping and combines it with TDMA. Channel hopping provides frequency sharing, which can avoid interference and reduce multipath fading effects. TDMA enables efficient low-power and reliable channel hopping communication because the synchronization of the slot and channel used by the communicating devices allows them to rendezvous in time and frequency, thus promoting successful communications.

Channel blacklisting of WirelessHART allows the network administrator to restrict the channel hopping to selected channels. For example, network administrators can blacklist channels in order to protect a wireless service that uses a fixed portion of 2.4 GHz band that would otherwise be shared by other WirelessHART devices.

7. Solution in 6LowPAN

Since 6LoWPAN and WiFi networks share the same frequency bands, overlap of channels and transmission power may generate interference which could increase the bit error rate (BER) for each networking technology as a result of both technologies being forced to share the physical layer.

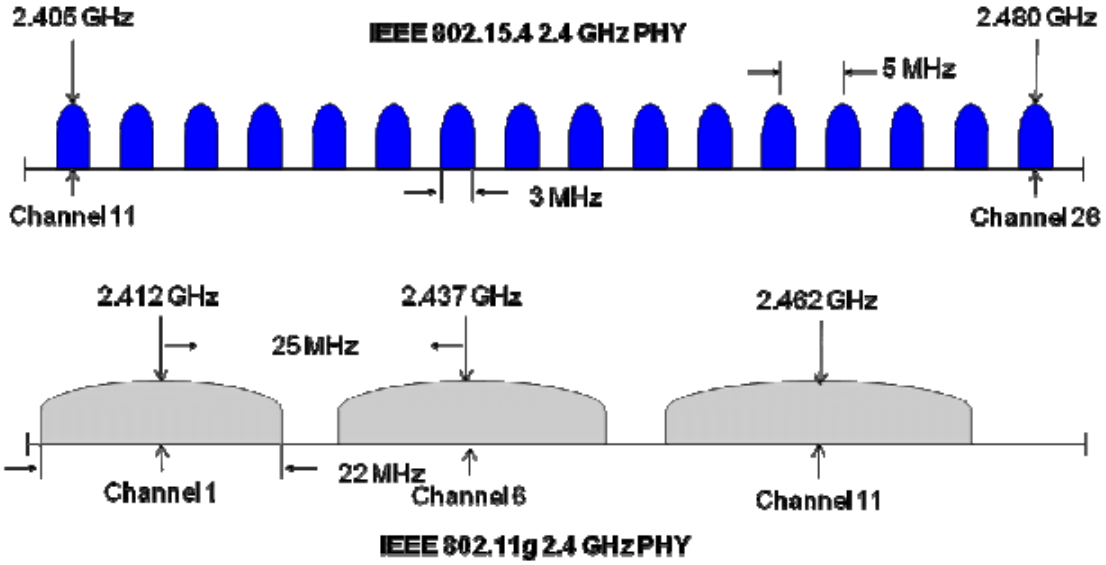

Figure 3: Overlap between channels

As shown above in Figure 3, there is no overlap between 6LowPAN channels 15, 20, 25, 26 and any of Wifi channels.

As a result of the site survey, network managers must review the default channel set-up of their 6LoWPAN and WiFi equipment to select the most appropriate channel(s), limiting potential sources of wireless interference and BER. The lower the degree of overlap between any technology and channel, the more stable the networks will be. Note that all devices on a given wireless network must be set-up with the same channel value.

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