A hotel is used to give a real world example of how this technology enables automated monitoring and control to give cost and service improvements that were not previously possible. An overview of the ZigBee networking standard is given and the basic elements of this network are introduced.

Several systems typically found in hotels are susceptible to wireless monitoring and control:

- Each room has a heating/ventilation/air conditioning (HVAC) unit and an associated thermostatic control to regulate the room temperature.
- Most modern hotels have electronic access systems which use magnetic stripe or punched hole cards to allow entry to the rooms. These cards are normally programmed at the front desk on check-in.
- Lighting – lamps, switches and remote controls
- Fire/smoke alarms and emergency lighting.

In today’s typical hotel, most of these systems are not operating on networks, and the systems operate independently of each other.

However, as a future hotel guest, wouldn’t it be great if:

- The hotel consumes less energy because unused rooms automatically have their heating or airconditioning units turned down, and their lights switched off.
- All of the above benefits become possible with a ZigBee-enabled wireless network.

What is ZigBee?

The ZigBee Alliance [1] is an open, rapidly growing, worldwide, non-profit industry consortium whose mission is to define reliable, cost-effective, low-power, wirelessly networked, monitoring, sensing and control products based on an open global standard.

Applications targeted by the ZigBee Alliance include residential and commercial building automation, industrial automation, games, toys, human interface devices, remote controls, medical monitoring, sports medicine and automotive. Primary requirements of these applications are

<table>
<thead>
<tr>
<th>PHY</th>
<th>Frequency Band</th>
<th>Channel Numbering</th>
<th>Channel Spacing</th>
<th>Modulation</th>
<th>Bit Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>868/915 MHz</td>
<td>868.0 – 868.6 MHz</td>
<td>0</td>
<td>N/A</td>
<td>BPSK</td>
<td>20 kbps</td>
</tr>
<tr>
<td>902-928 MHz</td>
<td>1 to 10</td>
<td>2 MHz</td>
<td>BPSK</td>
<td>40 kbps</td>
<td></td>
</tr>
<tr>
<td>2.4 GHz</td>
<td>2.4 – 2.4835 GHz</td>
<td>11 to 26</td>
<td>5 MHz</td>
<td>O-QPSK</td>
<td>250 kbps</td>
</tr>
</tbody>
</table>

Table 1. Frequency bands and data rates.
simplicity, long battery life, networking capabilities, reliability, and low cost.

ZigBee takes full advantage of a powerful physical radio and media access control defined by the US Institute of Electrical & Electronic Engineers in its 802.15.4 specification [2]. This specification defines how bits of data are converted into an actual radio transmission, and an efficient protocol for allowing multiple devices to share the same radio channel. In addition to this, the ZigBee standard adds software which defines how a network is built and operates, plus a standard way to add applications software. The ZigBee Alliance also provides interoperability testing, certification and branding.

**IEEE 802.15.4 radio overview**

The IEEE 802.15.4 standard defines two physical radios (PHYs) representing three licence-free frequency bands that include sixteen channels at 2.4 GHz, ten channels at 902 to 928 MHz, and one channel at 868 to 870 MHz. The maximum data rates for each band are 250 kbps, 40 kbps and 20 kbps, respectively. The 2.4 GHz band operates worldwide while the sub-1 GHz band operates in North America, Europe, and Australia/New Zealand. (Table 1). The IEEE standard is intended to conform to established regulations in Europe, Japan, Canada and the United States.

Both PHYs use direct sequence spread spectrum. The modulation type in the 2.4 GHz band is O-QPSK with a 32 PN-code length and an RF bandwidth of 2 MHz. In the sub-1 GHz bands, BPSK modulation is used with a 15 PN-code length and operating in an RF bandwidth of 600 kHz in Europe and 1200 kHz in North America.

**Zigbee wireless networks**

A ZigBee network consists of two or more ZigBee devices connected together. Various configurations are supported, including star, cluster tree and mesh. An important concept in ZigBee is the ability for many short-range radio devices to cover a large area by relaying messages across multiple “hops”. Thus a device at one end of the network can communicate with a device at the other even if they are far enough apart as to be out of each other’s direct radio range. Fig. 1 shows the different possible network configurations and the different types of ZigBee device.

**Reduced function device (RFD)**

An RFD is implemented with minimum RAM and ROM resources and designed to be a simple send and/or receive node in a larger network. With a reduced stack size, less memory is required, thus a less expensive IC. ZigBee RFDs are generally battery powered. RFDs can search for available networks, transfer data from its application as necessary, determine whether data is pending, request data from the network coordinator, and sleep for extended periods of time to reduce battery consumption. RFDs can only talk to a full function device (FFD) - a device with sufficient system resources for network routing.

**FFD**

A FFD requires somewhat more RAM and ROM resources in order to implement all the ZigBee functions. A FFD can serve as a network coordinator, a link coordinator or as just another communications device. Any FFD can talk to other FFDs and RFDs. FFDs discover other FFDs and RFDs to establish communications, and are typically line powered. A ZigBee network requires at least one FFD to act as network co-ordinator.

**Network co-ordinator, routers and end devices**

One of the FFDs must be designated as the ZigBee network coordinator, which initialises a network, manages network nodes, and stores network node information. The ZigBee router is a FFD which participates in the network by routing messages between paired nodes. The ZigBee end device acts as a leaf node in the network and can be an RFD or FFD.

**Applying ZigBee to an hotel**

The HVAC system is the obvious place to start implementing ZigBee in an hotel: the HVAC units are more or less ubiquitous in an hotel, so if each unit has a ZigBee node the hotel should be more or less completely covered by the wireless network. In addition the energy savings resulting from real-time control of the HVAC system should soon justify the installation costs.
HVAC and Zigbee

Since all the HVAC units are mains powered, it is possible to make all of them ZigBee full functional devices, which are always awake. Thus the HVAC ZigBee nodes can act as a backbone network which other battery powered ZigBee nodes can use for communication. Thermostatic heating controls, present in each guest room, can be implemented as ZigBee reduced function devices, since they have simple control/display functionality, connecting wirelessly with the ZigBee router node on the nearest HVAC unit. The heating controls are battery powered and can be wall-mounted in the most convenient place in the room. Since the heating control only transmits or receives information infrequently, it spends most of the time in sleep mode and can have a battery life measured in years.

Finally the network co-ordinator would be a FFD, most likely connected to a PC in the hotel management office. Software running on the PC allows the hotel manager to control and monitor the HVAC system for the entire hotel in real time.

ZigBee networked access

The next candidate for the application of ZigBee is the hotel’s electronic keylock access system. Adding a ZigBee node to each doorlock would allow the use of fixed keys – new ones do not have to be created for each new guest – and instead the doorlock itself would be wirelessly updated to allow/disallow access. Alternatively guests could be issued with ZigBee-enabled keycards. The wireless keycard is then detected as the guest reaches their room and the door automatically unlocked.

Both the doorlock and keycard need to run on batteries so they are implemented as RFDs, using the HVAC network as the communication backbone. Central control of the access system is once again via software on the hotel computer.

Lighting up with Zigbee

Connecting the hotel lighting to the ZigBee system control and monitoring network standard enables the vision of automated buildings to become a reality.

Connecting the hotel lighting to the ZigBee system offers the possibility to further automate the hotel’s systems. Adding a ZigBee node to each light allows:

- Placement of battery-powered wireless light switches/dimmers anywhere in a room, and moving them if needed in future
- Automatic notification of failed light bulbs
- Real-time control of all lights for optimum energy consumption
- Wireless remote control of lights for large rooms/auditoriums.

Since lights are always mains-powered they can be implemented as RFDs or FFDs. This could be decided at installation time based on location-specific factors. Battery powered switches would obviously be implemented as RFDs.

ZigBee emergency system

Battery operated smoke alarms, implemented as ZigBee RFDs, can be conveniently placed in every room. The existing ZigBee network is used to route signals between smoke detectors and other systems so that in the event of a fire:

- All smoke alarms sound
- Emergency lighting is switched on
- The hotel sprinkler system switches on automatically
- The hotel manager knows which device was the originator of the alarm.

In addition, individual smoke detectors can signal when their battery is low, enabling the hotel staff to ensure that all detectors are functional.

Conclusion

ZigBee low-power wireless networking technology offers the possibility to revolutionise the way commercial building systems are managed, providing an enhanced customer experience and reduced running costs. This article has examined the example of a hotel, but many of the systems discussed apply to all types of commercial or office buildings.

A low-cost, low-power wireless control and monitoring network standard enables the vision of automated buildings to become a reality. For more information, see www.freescale.com/zigbee

References

[1] The ZigBee Alliance: www.zigbee.org

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