

# WIRELESS SENSOR NETWORKS: INTERMEDIATE LAYERS

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## Abstract

The intermediate layers of the WSN protocol stack are the ones where the commercial and standard solutions are oriented. Some of those solutions are overlapped with lower and higher layers in order to achieve certain functionality. Some standard/commercial solutions such as Zigbee, Wibree, and Wireless Hart. Even though, every commercial or pseudo-standard solution claim that are suitable for a broad range of applications, including the indoor building monitoring, all the alternatives that have been studied show an important lack of efficiency regarding the self powering operation. In addition, the EnOcean, solution for self powered wireless communication link.

Keywords: Zigbee, Wibree, Wireless Hart, EnOcean

## I.Introduction

The main constraints and requirements for the proposed WSN architecture. The most important identified requests are summarized below:

**Scalability and support for Large Networks** (up to hundreds/thousands of nodes), that allow monitoring whole building scenarios. The self configuration of the network is considered an asset.

**Very Low Power design and operation** in order to achieve a real self-power behavior towards the perpetual operation.

**Very low cost for the nodes**, allowing affordable deployments even for large scale buildings.

**Standardized interfaces** to allow the coexistence and cooperating with existing systems.

## II. ZigBee

Zigbee[1] is a wireless networking standard that is aimed at remote control and sensor applications which is suitable for operation in harsh radio environments and in isolated locations. It builds on IEEE standard 802.15.4 [26] which defines the physical and MAC layers. Zigbee defines the application and security layer specifications enabling interoperability between products from different manufacturers.

While Bluetooth focuses on connectivity between large packet user devices, such as laptops, phones, and major peripherals, ZigBee is designed to provide highly efficient connectivity between small packet devices. As a result of its simplified operations, which are one to two full orders of magnitude less complex than a comparable Bluetooth device, pricing for ZigBee devices is extremely competitive, with full nodes available for a fraction of the cost of a Bluetooth node. ZigBee looks to control a light or send temperature data to a thermostat. While other wireless technologies are designed to run for hours or perhaps days on batteries. The main characteristics are

- Low power: the devices are “sleeping” most of the time. They only wake up when it is necessary to transmit the information.
- Supported topologies include: Peer to peer, star configuration, cluster tree and mesh network.



- Highly reliable and secure.
- Cost effective.
- Scalable and easy deployment.
- 250 kbps data rate.
- 10 to 75 m range.

## II. Zigbee Reliability

The reliability is an important requirement in a Wireless Sensor Network. A common Wireless Sensor Network could have a lot of nodes, so the information exchanged between devices must be accurate and reliable. Wrong data could affect the throughput of the network or could show an incorrect behavior. [1] Zigbee achieves high reliability in a number of ways:

- IEEE 802.15.4 with O-QPSK and DSSS
- CSMA-CA

- 16-bit CRCs
- Acknowledgments at each hop
- Mesh networking to find reliable route
- End-to-end acknowledgments to verify data made it to the destination

Zigbee specification oriented towards a robust radio technology. It uses O-QPSK (Offset-Quadrature Phase-Shift Keying) and DSSS (Direct Sequence Spread Spectrum), a combination of technologies that provides excellent performance in low signal-to-noise ratio environments. Besides, Zigbee uses CSMA-CA (Carrier Sense Multiple Access Collision Avoidance) to increase reliability. Before transmitting, ZigBee listens to the channel, when the channel is clear, Zigbee begins to transmit. This prevents radios from talking over one another, causing corrupted data. Another way that ZigBee achieves reliability is through mesh networking. Mesh networking essentially provides three enhanced capabilities to a wireless network: extended range through multi-hop, ad-hoc formation of the network, and most importantly automatic route discovery and self healing. This feature is very important in a wireless sensor network, in which every so often some nodes die or get removed, so the routes must be automatically updated.

The development of Zigbee technology is focused on the simplicity and low cost compared with other wireless networks, such as Bluetooth. There are different kinds of Zigbee nodes

**ZigBee Coordinator, ZC.** The most capable device, the coordinator forms the root of the network tree and might bridge to other networks. There is exactly one ZigBee coordinator in each network since it is the device that started the network originally.

**ZigBee Router, ZR.** As well as running an application function, a router can act as an intermediate router, passing on data from other devices.

**ZigBee End Device, ZED.** Contains just enough functionality to talk to the parent node (either the coordinator or a router); it cannot relay data from other devices. This relationship allows the node to be asleep a significant amount of the time thereby giving long battery life. A ZED requires the least amount of memory, and therefore can be less expensive to manufacture than a ZR or ZC

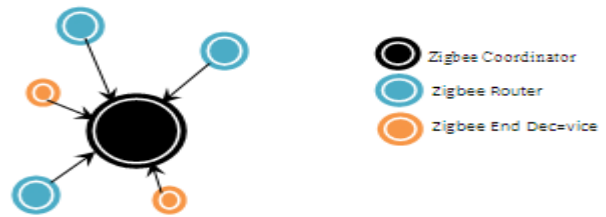


Fig 1 : Zigbee Network

### IIb. Comparison of Zigbee Stacks

FEATURES	ZIGBEE 2006	ZIGBEE 2007	ZIGBEE PRO
Size in ROM/RAM	Smallest	Small	Bigger
Stack Profile	0x01	0x01	0x02
Maximum hops	10	10	30
Maximum nodes in network	31,101	31,101	65,540
Mesh networking	Yes	Yes	Yes
Broadcasting	Yes	Yes	Yes
Tree routing	Yes	Yes	-
Frequency agility	-	Yes	Yes

Table 1: ZigBee Versions

### III. WIBREE (Low Power Bluetooth)

[2] Bluetooth technology is one of the most successful short range wireless communications technology incorporated into billions of devices from cellular phones, headsets and stereo headphones. Wibree is open standard based on the Bluetooth. The Wibree technology must have the same bit rate (1Mb/s) than the Bluetooth technology. All the specifications of Bluetooth and Wibree technologies are the same expect the power consumption of Wibree must be ten times inferior to the power consumption of Bluetooth. The frequency band is between 2.4 GHz and 2.4835 GHz. The channel bandwidth is 2 MHz. Bluetooth low energy technology (Wibree) is the next generation of wireless standard. It is a new design that has taken the best parts of the existing Bluetooth specifications and optimized it for a new set of applications. The main architecture of Wibree technology that can work in two ways:

**Stand alone.** Wibree can communicate with other stand alone Wibree chips and/or dual mode chips.

**Dual mode.** Wibree can communicate with other stand alone or dual mode Wibree chips in addition to other Bluetooth chips.

The core values of Bluetooth low energy technology are as follows:

- Low power. Wibree improves the energy efficiency when devices are connectable and discoverable, and also enables devices to send a small quantity of data very quickly from a disconnected state. These new low power features enable new market segments where there is a need to transmit only small amounts of data.
- Low cost. Wibree reduce these costs, by relaxing important specification parameters, and by reducing the implementation size significantly.
- Short range. Wibree enables similar ranges as Bluetooth technology, about 10 m.
- Worldwide. Wibree can be used and sold in almost every country on the planet. Therefore, Wibree enables a single seamless market for wireless devices, enabling huge mass market, rather than country or regional specifications or devices.
- Robust. Wibree has a robust radio which is essential when you are trying to gather a measurement from a sensor, or controlling something.
- Web Service Integration. Devices can send a small quantity of data to a web service. This feature is a key feature for a large number of use cases.
- Fast Connections. The time it takes to make a connection, and send some data is very important to reduce battery life. Wibree devices can wake up, connect and send some application data, and then disconnect again within 3 ms.
- Interoperable Sensors. Wibree allows to create of fully interoperable devices.
- Network nodes: Wibree is a low-power networking technology that links a small number of nodes to devices such as computers and mobile phones.

**Fig 2: Wibree Stack**

#### IV. Wireless HART

[4] WirelessHart is another 802.15.4 standard. This is a more specialized standard, which is used in factory and process control, where it adds wireless connectivity to the existing wired HART standard. The WirelessHart technology was designed to enable secure industrial wireless sensor network communications while ensuring ease-of-use is not compromised. Security is built-in and cannot be disabled. It is implemented with end-to-end sessions utilizing AES-128 bit encryption. These sessions ensure that messages are enciphered such that only the final destination can decipher and utilize the payload created by a source device.

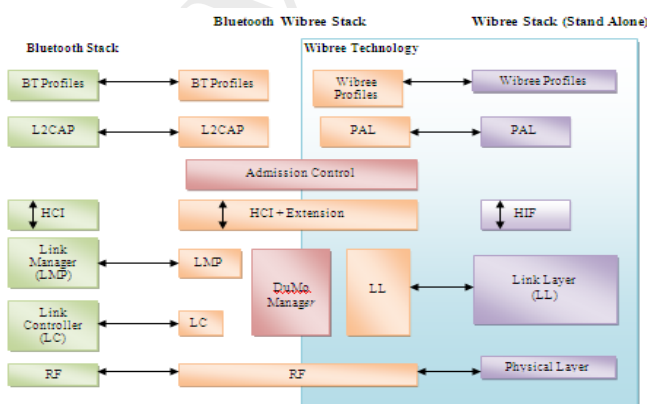
[3] WirelessHart is a fully featured mesh network containing field devices (sensor nodes), gateways and a network manager responsible for configuring and maintaining the network. WirelessHart uses synchronized communications between devices, with all transmissions occurring in pre-scheduled timeslots. That also allows it to implement channel hopping, with automatic, coordinated, hopping between channels to increase its immunity to interference. As a result, it can define QoS for transmissions, which is important for process control applications.

In a WirelessHART deployment, the network management is made by a global network manager. This element is the responsible for configuring the network, scheduling communications between devices and managing message routes, instead of making in each node. This feature involves having a central system running all the time to give the schedule support, as well as generating a lot of traffic between the sensor nodes and the manager. The key capabilities are,

- **Reliability** even in the presence of interference, thanks to technology like mesh networking, channel hopping and time-synchronized messaging.
- **Security** and privacy for network communications though encryption, verification, authentication and key management.
- **Effective power management** through Smart Data Publishing and other techniques that make batteries, solar and other low-power options theoretically viable for wireless devices.

#### Stack Architecture

- **Physical Layer.** It is based on IEEE 802.15.4 with a data rate of 250 kbps and operating frequency of 2400-2483, 5 Mhz. Modulation used is DSSS.



- **Data-link layer.** It is responsible for the secure, reliable, error free communication of data between HART compatible devices. For collision free communication, WirelessHart uses TDMA and channel hopping.
- **Network layer.** This layer provides routing and end-to-end security.
- **Transport layer.** This is a thin layer in WirelessHART, which ensures reliable data transmission. It manages sessions for end to end communication with corresponding devices.
- **Application layer.** It uses the standard HART application layer, which is command based.
- **Co-Existence,** problems can occur when two or more packets of information are transmitted at the same time and frequency such that they “collide” in the same physical space. If networks aren’t designed to minimize or avoid these occurrences, unreliable communications will result.

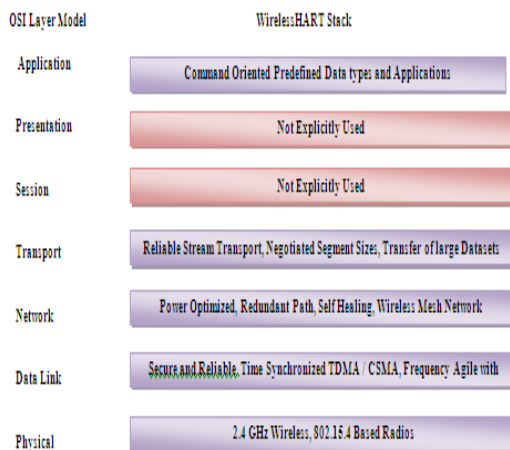


Fig 3 – Wireless Hart Stack

There are several techniques that can be used to minimize network interference:

- **Channel hopping.** WirelessHart instruments use a pseudo-random channel hopping sequence to reduce the chance of interference with other networks.
- **Time division Multiplexing.** A WirelessHart network utilizes Time Division Multiple Access (TDMA) technology to ensure that only one instrument is talking on a channel at any given time.
- **DSSS.**
- **Mesh Networking.** Each WirelessHART filed instrument is capable of routing the message of other

instruments along a route that will ensure the message is received at its ultimate

- gateway destination.
- **Blacklisting and Channel Assessment.** In conjunction with channel hopping the Wireless HART network can be configured to avoid specific channels that are highly utilized by other networks and therefore likely to provide interference. To further avoid any conflict with other neighboring networks a WirelessHART instrument listens to the frequency channel prior to transmitting data. If other transmissions are detect the WirelessHART instrument will back off and attempt the communication in another timeslot on a different frequency.

The WirelessHART technology was designed specifically to work in the 2.4 GHz ISM band in an environment where other wireless networks are expected to be found. Using the techniques above, allow a WirelessHART network to maintain high data reliability and at the same time minimize, if not eliminate, any effect it has on other overlapping networks.

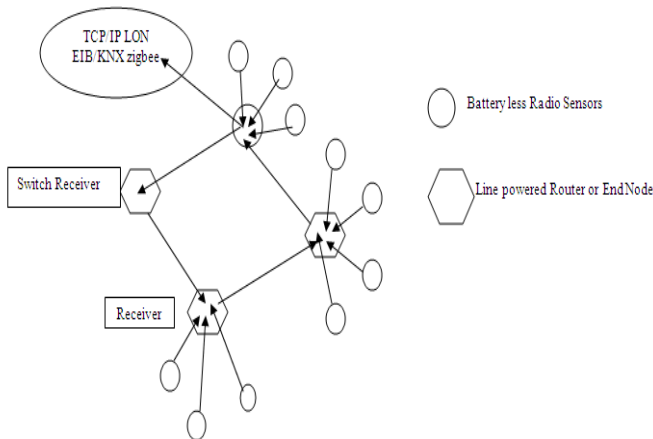
## V. EnOcean

EnOcean[14] Alliance is, as ZigBee Alliance, a consortium of companies trying to develop a common standard for communications and application profiles in the WSN world. Even though EnOcean claims to be simplest and more efficient than Zigbee, it is only focused to some application areas such as HVAC or light switching.

EnOcean technology is more focused on point-to-point connections, uni- or bi-directional, paying not so much attention in supporting complex network topologies such as mesh networking. Although EnOcean products claim for being battery-less devices, there must always be at least one power supplied repeater device. Every EnOcean remote sensor/switch/actuator communicates directly with a central repeater, which can be connected to other repeaters or be a bridge to a wired bus such as LON, KNX, etc.

Another inconvenient for the current project scenario is the radio protocol of EnOcean technology. Its MAC layer (medium access control) relies on the fact that, as a packet (frame) transmission needs less than a millisecond to be completed, the probability of a collision is very low. So, although there could be many devices (hundreds), they would successfully communicate mostly in a single transmission attempt. But in case of collision, which in a large network could be quite probable, EnOcean devices send their data frames repeatedly within a few milliseconds, randomly offset

from one to another in time, in order to avoid collision. This mechanism conflicts with the power aware specification.



**Fig 4 - EnOcean Wireless Links with battery-less nodes.**

## VI. Results

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As one of the goals of to deploy a WSN being self-powered, self configurable, fully bidirectional, with low latency and easily upgradable, a synchronized (mesh) network is needed. EnOcean technology is not well suited

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