



“ZigBee Competitive Technology Analysis”

Section Summary

*Steinbeis-Transfer-Centre for Embedded Design and Networking
Steinbeis-Research Center Wireless Communication
University of Cooperative Education Loerrach
Prof. Dr.-Ing. Axel Sikora*

Revision	Date	Author	Changes
0.1	11.06.2006	AS	initial version
0.11	13.06.2006	AS	rework of ch. 5.6; aspects added to the SWOT-tables rework of summary
0.2	13.07.2006	AS	rework of SWOT-tables, partially based on the input from the ZigBee Members Meeting June, 14 th , in San José and from Zachary Smith (received July, 9 th)
0.3	25.07.2006	AS	Introduction of Short Version for Press Release (new ch. 11) based on input from G. Martin (received July, 24 th)
0.4	20.09.2006	Brent Hodges	General review from the ZigBee Alliance
0.41	21.09.2006	AS	Minor comments and adaptations to V0.4
0.42	23.10.2006	Brent Hodges	Minor comments and changes
1.0	2.11.2006	AS	Two minor changes, preparation of final version

1 Summary

When reading the analysis, it appears that the reviewed technologies take different approaches, but can be analyzed using a set of common characteristics. Review these characteristics below to understand the main findings for each aspect.

- 1) All of the technologies are young – Bluetooth being the oldest with developments started in 1997. ZigBee started its developments in 2001. Different companies developed other technologies within the last three or four years. Ongoing developments for all technologies continue.
- 2) The original market involves different target technologies' applications, such as:
 - Whereas IEEE802.15.1 and Bluetooth first targeted consumer and communication applications (where it found its undisputed place), companies soon used it for cable replacements in basically all other applications. It gained a good foothold in industrial point-to-point and point-to-multipoint-communication in medical surveillance and many other application fields.
 - IEEE802.15.4 and ZigBee take a general approach in addressing wireless sensor networks required for three targeted market areas: residential home control, commercial building control, and industrial plant management – all on a professional level. Many Zigbee companies develop and consider other applications. Examples include:-medical, security, environmental, automated meter reading, energy management, telecommunications and other consumer uses. Zigbee targets key characteristics such as low power and cost, and the need for networking devices as opposed to the point-to-point networks found for most Bluetooth and Wi-Fi applications.

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- Insteon addresses the low-end home automation market.
 - Z-Wave actively works with home automation applications.
- 3) All technologies cover a complete protocol stack from physical layer (layer 1) through application layer (layer 7). All have incompatible interfaces with each other related to their development paths and target markets. Only ZigBee through IEEE802.15.4 allows the direct integration into the IEEE802-family and its (however rarely used) LLC-APIs. The stacks for the different technologies vary in complexity, where Bluetooth and ZigBee follow the most open and flexible approach. ZigBee's specification document is much shorter and allows a small and simple stack. Insteon and Z-Wave also have small stack sizes.
- 4) All of the evaluated technologies use RF-technology for communication. However, each takes a different approach with its implementation.
- Bluetooth uses the 2.4 GHz frequency band to achieve higher bandwidth and world-wide marketability.
 - ZigBee is the only technology that uses 2.4 GHz and sub-GHz-frequency bands. This approach allows designers to make their own decisions about which frequency band best fits their application. ZigBee uses the 2.4 GHz frequency band for higher bandwidth and world-wide acceptance along with the ETSI 868 MHz and the FCC 900 MHz bands.
 - Insteon and Z-Wave use sub-GHz-frequency bands. Z-Wave uses the ETSI 868 MHz and the FCC 900 MHz bands, while Insteon currently covers only the FCC-bands.

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- In addition, Insteon offers a hybrid approach of powerline and RF-technologies, and thus, combines two “no-new-wires” technologies.
 - Bluetooth and ZigBee use spread-spectrum technologies to avoid multi-path fading and increase robustness. This approach allows for improved signal immunity in the presence of radio interference. Insteon and Z-Wave use narrowband technology for better bandwidth efficiency.

The laws of physics dictate that for a given output power the sub-GHz frequencies provide longer range, which the analysis shows in various independent measurements. However, the sub-GHz systems suffer from lower bandwidth, duty-cycle limitations (in Europe), interference from other systems in the same frequency (900 MHz cordless phones in the U.S.) and from various world-wide regulatory issues.

In contrast, 2.4 GHz-systems allow larger bandwidth and almost world-wide availability. However, coexistence with other 2.4 GHz systems (e.g., WLAN or analog Video) and decreased range especially for indoor applications must be considered.

- 5) On the medium access layer, the technologies also take a different approach.
- For medium access, Bluetooth uses a master-slave system, whereas all other systems use a CSMA/CA system.
 - Addresses for Bluetooth and ZigBee are IEEE-compatible, whereas Insteon and Z-Wave use their manufacturer's proprietary addressing scheme.
 - Extensive power-down modes create the pre-condition to build battery-powered systems with several-year maintenance periods required for installations with a

large number of sensor nodes. All technologies except Bluetooth inherently include power-down modes.

However, apart from the mere integration into the specification, it requires efficient hardware support to make use of those modes. The main stepping stone includes low-power oscillators and fast wake-up times.

Network setup that consists of several nodes requires the networking layer and routing. Here, the following approaches can be observed:

- Bluetooth does not provide a robust networking solution required by most targeted applications. It only needs point-to-point connectivity. Bluetooth does define a Scatternet, which is not in practical use due to the specification's large number of options and white spots.
- ZigBee offers a variety of routing algorithms, including hierarchical tree, neighbor and table-based routing. The protocols show a high degree of flexibility and stability, with explicit functions of entering and leaving a network. A large part of the protocol automatically manages orphaned devices.
- Z-Wave comes with a source routing approach, which puts the complexity from the intermediate to the end nodes. The protocol does not support orphaned devices, automatic entering and leaving a network and lost network connectivity, however, provides a low-complexity solution.
- Insteon uses a repeating algorithm for its multi-hopping. Since the repeating nodes connect to the power line communication, time synchronization can be provided for all repeating nodes. Therefore, Insteon runs a "Simulcast" scheme with a simultaneous repetition of the frames.

6) On the application level, all technologies attempt to achieve interoperability of different products through specification of application profiles.

- Bluetooth defines a multitude of application profiles. However, for most applications apart from the standard voice or data communication, it uses either proprietary profiles or application based on the serial-port profile.
- ZigBee defines a lighting-control public profile for use as a template. Members drive activities within the ZigBee Alliance to develop many public application profiles for use by all Alliance members. Apart from these public profiles developed and adopted by the ZigBee Alliance, OEMs can create their own proprietary or “private” profiles.
- Insteon’s application profiles work with device category and descriptors assigned by Insteon’s sister company, Smarthome, to the customer. The device manufacturer defines and creates functionality for these devices.
- Z-Wave currently defines approximately 20 profiles for use in its home automation applications.

7) Security is a major stepping stone for wireless networks. One should always consider the potential security risk and the probability of an attack. Whereas the risk for a simple light-switching installation could be considered low, risks grow with the introduction of alarm systems or gateways to PC networks. For industrial applications, security is a major stepping stone. Security concerns involve much more than an encryption engine in software or hardware, but a whole system of key generation and distribution, and encryption and authentication. In this respect, major differences are regarded below. Only Bluetooth and ZigBee provide full security approaches:

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- Bluetooth comes with its own system of cryptographic algorithms to address these issues. Despite some minor flaws, the security system has a good reputation with no known major attacks as long as the implementation fulfills certain requirements.
 - ZigBee uses a tiered approach to security. At the lower level, IEEE802.15.4 provides AES encryption. On top of that, ZigBee defines a security toolbox for key generation and distribution, which can support multiple modes for residential, commercial and industrial application.
 - Z-Wave does not define a security system. In the past, Z-Wave provided a 3DES encryption engine for its 100-series, but eliminated this in the current 200-series.
 - Insteon comes with the option to use an easy rolling code system. Current understanding suggests this is not an encryption system, and therefore, can be easily compromised.
- 8) Certification: Once all these protocols are defined, it is critical that they interoperate, especially since different manufacturers can provide them. Product certification programs should be used to guarantee the technologies perform as promised. The following provide glaring differences in approaches used by the different technologies:
- Bluetooth has year-long (sometimes painful) experience with interoperability tests. A Bluetooth certification program is in place, which has improved the situation. However, running a full Bluetooth certification process creates costs and consumes time. This makes predefined Bluetooth stacks and platforms very popular.

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- ZigBee implements two certification programs: platforms and products. To date, ZigBee certified 13 ZigBee-Compliant Platforms. ZigBee is in the process to certify its first ZigBee OEM products. The necessity for ZigBee comes with a large number of choices the standard allows on each level. In order to guarantee interoperability, it requires OEMs who wish to establish interoperability for “private” application profiles to use Zigbee Public Application Profiles or pre-defined stack and application profiles. Third-party laboratories perform platform and product certification for Zigbee Alliance members to guarantee impartiality and ensure products perform to expectations.
 - Z-Wave allows a self-certification from the system developer, which is only verified by the Z-Wave-Alliance. This reduces costs, but doesn't provide impartiality and creates known process weaknesses. Z-Wave's creator Zensys promises future improvements.
 - Insteon has no established certification procedure.
- 9) Alliances: It is not technology that creates the market success, but market readiness and the players behind the technology that promote it. Two of the technologies, Bluetooth and ZigBee, take the approach of developing an open multi-vendor standard. The two others first provided proprietary products and now rally a developer community to create the appearance of openness.
- Bluetooth and ZigBee, large international, multi-vendor alliances, unite large semiconductor and OEM manufacturers. In addition, analysis shows that a substantial world-wide scientific and engineering community works with and for those technologies.
 - Z-Wave and Insteon, typical single-vendor customer coalitions, are not alliances. Although they have a number of members, they do not combine competitors

on all levels of the value-chain. The development of the technology itself is mainly limited to the original companies.

The wireless networking industry continues to demand the most efficient approach for bringing development costs and device costs down. While there is no one clear-cut solution, vendors and alliances continue to work to build a flexible range of solutions that cater to different markets.

For a more detailed discussion of these and many more aspects, please read the full report, which can be found at <http://www.stzedn.de>.