Wireless Sensor Networks: Standards and Driving Forces

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Abstract. The paper will provide a state-of-the-art report of Wireless Sensor Networking technologies, including ZigBee, WirelessHART, LowPower Bluetooth and others. The main advantages and drawbacks of these technologies will be described, focusing on application-driven requirements. Special focus will be put on standardization activities in the areas of WSN design itself, as well as domain-specific WSN-related standards (Energy, Industry, Healthcare and Environmental). A review of application frameworks will also be provided, including OS-level platforms (TinyOS, Contiki OS).

1 Introduction

Following a period of relative stagnation, Wireless Sensor Networks now enjoy time of rapid growth, facilitated by renewed interest in conservative resource consumption and increasing usage of service infrastructures. Applications of WSN adopted now in many areas, including Energy, Industry, Healthcare, Environmental Monitoring and others. Among numerous advantages, provided by Wireless Sensor Networks, a special emphasis can be put on possibility to create systems, optimized for environment and thus consuming less of resources, easily deployable and offering non-intrusive behavioral characteristics.

Introduction of WSN into the real life applications is following a number of trends, including industrial efforts for standardization of technologies, governmental activities to promote certain application scenarios, scientific research in the areas of technological platforms for WSN (including radio data transmission, communication network architectures and protocols, energy harvesting techniques, etc.). In this paper, we will try to sketch a global picture of WSN technologies and applications from a point of view of industrial adopters.

2 Communication Technologies

Wireless Sensor Network communication technologies include results of research and development activities in the areas of radio communication, networking protocols, software architectures and platforms. Development and standardization of WSN is driven by several communities, including:

1. Internet community

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2. Industrial associations
3. Technology groups

Often, standards development is going in similar directions and some standards overlap significantly in purpose and/or approach to implementation. Therefore knowledge of existing WSN options, taking into account technical and marketing aspects, is essential to select the right approach for a project or product.

2.1 IEEE 802.15.4

IEEE 802.15.4 is one of the most promising standards for Wireless Personal Area Networks (WPAN). It is available since 2003 and serves as a basis for several higher level protocols, including ZigBee, WirelessHART and 6LoWPAN. IEEE 802.15.4 [1] defines physical and MAC layers (including security) and supports star and peer-to-peer topologies. Data transfer rate is up to 250 kb/s. Supported bands and modulations are changing depending on a standard version (2003, 2006 and 2007 versions available), but the most common is 2.4 GHz band with 16 channels. IEEE 802.15.4 can be used "as is" only for very simple applications].

2.2 6LoWPAN

IPv6 over Low power WPAN (6LoWPAN) is IETF working group, aiming to bring IP networks (IPv6) and sensor networks together. The problem with integration of IP and sensor networks is in significant overhead of IP protocol headers, which are not suitable for IEEE 802.15.4 networks (with 127 bytes data frame). 6LoWPAN WG has completed IETF RFC 4944 [2], defining a way for transmission of IPv6 packets over IEEE 802.15.4 networks, basically using stateless headers compression. Usage of IP is promoted by IP for Smart Objects (IPSO) Alliance as a native way for integration of sensor networks and smart objects with existing IT infrastructure.

2.3 ZigBee

ZigBee Allience is an industrial association, developing and promoting ZigBee protocol standard [3]. ZigBee protocol is a layer above IEEE 802.15.4, which provides networking layer with support for different architectures, including star, tree and most interesting – mesh topology. ZigBee specification is a mature one, first version released in 2004 and used by some commercial products. Special focus of the Alliance is on application level standardization, i.e. definition of standard interfaces for different application domains, including Home Automation, Smart Energy, Building Automation, Health Care and others.

2.4 Wireless HART

HART is an industrial protocol for communication between field instrumentation and host systems. Wireless HART is a part of HART 7 Specification [4], and as ZigBee, provides extension over IEEE 802.15.4 layers with industrial specifics, such as necessity for real-time operations. It defines communication network structure and necessary components, such as Network Manager. Wireless HART uses channel hopping TDMA protocol with 10 ms communication slots. HART specification includes also application level elements, such as definition for formats of diagnostic information, which are applicable for Wireless HART devices also.

2.5 ISA100

ISA100 Wireless Compliance Institute aims to define a complete set of industrial wireless standards. One of these standards, ISA100.11a [5], is covering wireless process control applications. From the maturity point of view, it is rather new (2008) and very similar to Wireless HART from the technical perspective. This is also based on IEEE 802.15.4-2006, uses channel hopping to increase robustness and provides star topology for better response time and mesh topology for reliable communication. Very interesting particularity of this standard is that it provides inter-networking routing and frame format in accordance to IETF RFC 4944. Special attention is also paid to interoperability with other families of standards (ZigBee, Wireless HART, etc.).

2.6 Bluetooth Low Energy

Development of Bluetooth Low Energy is currently ongoing and specification is planned in the beginning of 2009. It is based on Nokia Webree and targeted to similar applications as IEEE 802.15.4; advantage of Bluetooth Low Energy is availability and cost of radio hardware (existing Bluetooth radios can be used in many cases). However, applicability of this standard is limited to consumer devices, i.e. industrial scenarios are not covered.

2.7 Other Solutions

There are many other solutions exist on a market, most of them proprietary and targeted to certain specific applications. The list includes, but not limited to Z-Wave (the main competitor to ZigBee), KNX RF, EnOcean and others. Often development of particular technology is driven mostly by one company, and this makes investments into this technology rather risky.

3 Wireless Sensor Platforms

Wiireless Sensor Platforms are hardware/software solutions to enable development of WSN applications. These solutions usually have very special architecture due to application requirements, i.e. include very low-power hardware (this means low performance and small amount of memory) and low overhead software components, including OS, drivers, protocol stacks, application services, etc. Usually, platforms are centered around particular operating system, which is adopted for WSN needs.

3.1 TinyOS

TinyOS is an open source component-based operating system, designed for embedded Wireless Sensor Networks. TinyOS is written on nesC, a dialect of C designed for sensor applications with limited resources. Due to openness, portability and component architecture, TinyOS used in many projects and some ZigBee stack implementations use it as an underlying platform. However, TinyOS networking model is not standard and without usage of some common protocol is more suited for research activities, rather then industrial applications. Another limiting factor is usage of nesC language – with all simplicity it is a new programming language to learn by developer.

3.2 Contiki OS

Contiki OS is another open source embedded platform for WSN applications. It is implemented in C and similar to TinyOS, provides a broad spectrum of supported hardware architectures, system modules and user tools. Very interesting particularity of Contiki is IP networking stack, which actually led to IETF standard development and IPSO Alliance creation. Contiki also used by Freaklabs FreakZ open source ZigBee stack implementation project, so it has potential to cover both most perspective WSN networking directions.

3.3 Linux

Linux is traditionally considered as a backbone for a modern networking infrastructure. In our days it is not only adopted in server equipment, but also used in network appliances, such as routers, media streaming centers, etc. In the same time it is selected by some manufacturers as a platform for mobile handsets. From author point of view, this makes Linux an ideal platform for gateways between wireless sensor networks and traditional network infrastructures, including computer and mobile networks. The main blocking factor is the absence of proven implementations of WSN protocols for Linux operating system. However, this situation is being changed by Linux-ZigBee SourceForge.net project, which aims to develop a ZigBee (and more generally – LoWPAN) protocols stack for Linux kernel.

4 Application Domains

Adoption of Wireless Sensor Network technologies is driven by application requirements. There are some “natural” areas where need in WSN obvious – for example home automation, environmental monitoring or tracking applications. Other applications are “triggered” by specific governmental actions; a good example here is smart metering technology.

4.1 Energy (Metering)

Advanced Metering is a very hot topic in US and Europe, due to governmental plans to update electricity grid and facilitate energy saving technologies. Electricity metering, is not connected directly to WSN topic, however there is a synergy with home automation, which could bring significant benefits by enabling smart meters to communicate with in-house smart appliances, for example to schedule or control energy consumption. This was understood by ZigBee Alliance and triggered development of Smart Energy profile. However, state-level standards for metering are not yet developed, so it is not clear if WSN will be adopted at the end as an enabler technology for Advanced Metering Infrastructures.

4.2 Industry (Manufacturing)

Wireless technologies in industrial automation are adopted rather slowly due to significant products lifecycle and conservative approach to engineering. This area has many specific requirements for reliability and real-time operation; main standardization activities are done by International Society of Automation. However advantages of WSN for industry are so significant, that 2 of most mature WSN standards (Wireless HART and ISA100.11a) are targeting industrial process control applications.

4.3 Health Care

In healthcare industry, most of the advantages of Wireless Sensor Networks are usually connected to “personalized healthcare” concept. Development of standards in this area is mostly driven by Continua Health Alliance, defining technologies and interoperability requirements for the industry. There are specific requirements for healthcare applications, mostly in the area of security and reliability of operation. However from technology point of view, mostly common approaches and standards are adopted, for example careful attention is paid to possibility of mobile technology integration with healthcare services, and this means usage of Bluetooth (at the time of writing, evaluation and selection of wireless technology by Continua was still in progress).

4.4 Environmental Monitoring

This is a native application of Wireless Sensor Networks and it has a lot of attention from research community. However, there are no significant moves to define common standards in this area, probably due to significant diversity of possible use cases. For example, wireless sensor networks are adopted for pipeline infrastructures monitoring, dikes, bridges and pollution control.

5 Conclusions

Wireless Sensor Networks standardization process is rapidly progressing, driven by introduction of new application scenarios, market forces and governmental regulation activities. The number of already published standards, often for similar (or same) applications, raises concern for interoperability of different networking technologies. Usage of common platforms for networking infrastructure may help to overcome this potential problem and help to create single world wide “Internet of Things”.

References

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