6LOWPAN AND IEEE 802.15.4 FOR PERSONAL AREA NETWORKS

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Abstract. This paper presents a practical standardized wireless transmission technique for personal area networks (PAN) and general sensor actor networks. Applications include house automation, for industrial applications and for homes and Ambient Assisted Living (AAL) among others. IEEE 802.15.4 and 6LoWPAN form together a complete protocol stack which is compatible with IPv6 and IPv4. It is desribed how these procedures an be used as the basis of wireless low data rate short distance networks.

I. INTRODUCTION

Since WLAN is develops towards increasing higher data rates, there is a large number of applications for wireless technologies, which do not necessarily need high data rates in the first place. Many applications in home automation, industrial control and monitoring should be optimized to the specific requirements. Examples include designs that enables low energy consumption and hence a long battery life or the usage of micro energy harvesting, or the ability to build sensor-actor-networks, possibly with multihop capability and with short network join times. Important application of such low data rate networks can be seen in the context of industry 4.0, in the automation of commercial building, but also increasingly in private homes, to make life easier. For home automation the applications range from simple control of light, air conditioning to meter control and house security systems. In the future elderly or handicapped people might need technical support if they like to live longer in their familiar environment. This is the idea of ambient assisted living (AAL), to give technical support for people in their living situation, in their homes as well for their medial monitoring. Since such applications are highly interconnected and cables are unwanted, advanced wireless communication methods, like the ones presented in this paper, are required. These wireless techniques offer an alternative to cables, possibly without recharging or changing of batteries or regularly surveillance by technicians. Therefore it is desirable to have systems that are

- fault tolerant
- highly available
- small
- using minimal technical effort, hence cheap
- able to run for years without changing any batteries
- equipped with a simple and intuitive user interface.

There are some systems in use for short range, low data rate communication. Examples are ZWave, or the wide spread system EnOcean, which is a which needs only minimal amount of energy for the transmission of wireless packages and integrates the use of energy harvesting. ZigBee, among others are works also with the here presented IEEE Standard 802.14.4 in the physical and data link layer.

In the following, the standards IEEE 802.14.4 and the TCPIP related standards 6LowPan are introduced. It is further shown, how to the operation is done using a special operation system for the nodes and the benefits are discussed.

IEEE 802.15.4

The Standard IEEE 802.15.4 is desribed in [1] and is defined for low-rate wireless personal area networks (LR-WPANs) and can work in a range from 10 to 100 meter. The protocol specifies the physical layer and medium access control, and represents hence the two lowest layers of the OSI model. Hence it might me used as a basis for higher layer protocols like ZigBee, Wireless HART and as described here in this paper: 6LowPAN. The nodes use the ISM frequency bands (i.e. the unlicensed frequencies for industrial, scientific and medical application) for wireless transmission. Here these are frequencies in the 868 MHz Band in Europe and Asia, the 915 MHz in North America and the international widely used band around 2.5 GHz .

The physical layer of IEEE 802.15.4 standardizes different modulation techniques for a robust wireless communication and forms the bases for a collection of different types of actor sensor networks. Additional to the legacy standard a collection of optional extension is available. One option is the ASK technique defined for the 868 MHz and 915 MHz frequency band and another is the Offset Quadrature Phase Shift Keying (O-QPSK).

One important characteristic of this standard is the small packet size of 127 Bytes In many cases of the applications mentioned above, this is sufficient to transmit sensor and actor data though a multihop network. The transfer rate reaches from 20 Kbit/s to 250 Kbit/s depending on the actual used frequency band.

The MAC Layer supports two modes of operation. The beacon mode uses Time Division Multiple Access (TDMA) which guarantees time slots to network-participants and handles the node association. The beacons are sent by the network coordinator, i.e. a special node acting like a access point access point. It informs the clients about the Contention-Access-Period (CAP), the Contention-Free-Period (CFP) or the inactive period of the network. During the inactive period the nodes can switch of their power (sleeping period). The alternative to the Beacon Mode is the Carrier Sense Multiple Access (CSMA) to allocate the wireless channel, similar to the similar procedure in Ethernet.

The MAC Header as shown in Fig. 1 contains the destination and source address and the PAN address. The address size is 16 or 64 Bit, enough for every node in a network to have a unique identification number.

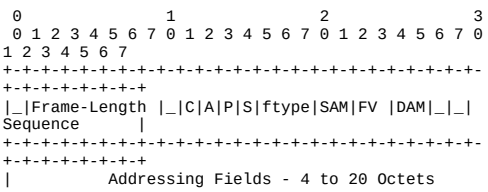

Fig. 1 Schematic view of IEEE 802.15.4 Data-Frame and PHY-Packet

6LoWPAN

The Standard 6LoWPAN is fixed in a number of RFCs by the Internet Engineering Task Force (IETF), specific in the 6LoWPAN Working Group. It is defined in [2] and further additional internet-drafts by the IETF. The TCP header compression for 6LoWPAN is defined in [3]. This group of standard defines IPv6-based protocol stack in the layer 3, 4 and 5. It uses the layers 1 and 2 from the IEEE 802.15.4. The stack is shown in figure 2.

To be able to keep the data packets small, a technique named header compression is used. Instead of using the full IPv6 addresses, the long addresses are substituted by short local addresses in the actual network. But still the compatibility with IPv6 is maintained. The Internet Control Message Protocol version 6 is used in 6LoWPAN for establishing and maintaining the PAN (personal are network). Usually 6LoWPAN is used together with UDP as a minimal Transport Layer which is compressed to. The 6LoWPAN working group is even discussing a compressed version of TCP.

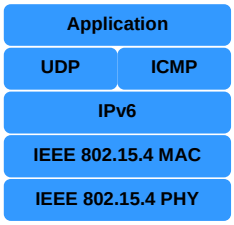

Fig. 2 6LoWPAN Protocol Stack

6LoWPAN networks usually consist of tiny embedded devices, which shall be connected to the outer IPv6 internet by a border router, which performs the necessary compression and decompression of data packets from and to the PAN. A good description can be found in [4].

An IEEE 802.15.4 frame has a maximum size of 127 Bytes and in worst case there are only 72 Bytes left for MPDU. 6LoWPAN Header Compression makes it possible to shrink a usual IPv6/UDP-header with around 48 Bytes in size to at best 6 Bytes by leaving out redundant data that is given by the context, see figure 3. So there is (at best) 108 Byte space for application-payload. If packets do not fit into one packet, they can be fragmented.

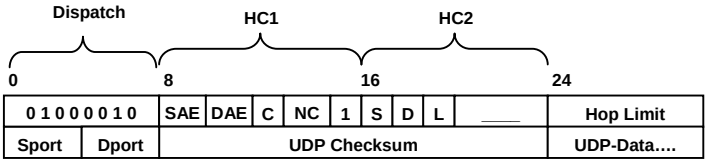

Fig. 3 Compressed 6LoWPAN-Header and UDP-Header

By now there is no standardized way of routing in 6LoWPAN, partially because routing is treated apart from the 6LoWPAN working group. In 2008 a new working group called Routing Over Low-power and Lossy Networks (ROLL) was founded to deal with that topic in particular, (see [5]-[7]). Their protocol called IPv6 Routing Protocol or Low Power and Lossy Networks (RPL) exists currently in its 17th version and is under evaluation by the IESG to become an internet standard.

As sensor networks can scale from few to thousands of nodes, memory and computing resources are very rare, but a routing protocol needs certain resources. The method RPL establishes a Distance Oriented Directed Acyclic Graph (DODAG) rooting algorithm, keeping the topology in the border router and facilitates routing in a hierarchical fashion. Simulations with a network of 45 nodes have shown that 90% of all nodes need to store less than 10 nodes in their routing tables and that routing control traffic is negligible in respect to the data traffic-rate.

Operating Systems and Hardware Platforms

The described stack is available on a variety of operating system specialized on embedded devices and sensor networks. In the developed test network at the HTW the version 6LoWPAN-Nanostack 1.1.0 was used with the operation system FreeRTOS. Several other 6LoWPAN stacks are available for TinyOS, Contiki and other operation systems. These operation systems can also work in other adaptation with ZigBee.

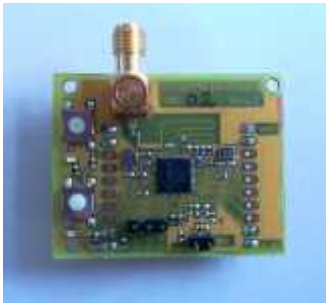

Fig. 4 Radio Engineering Group at the HTW-Berlin - 6LoWPAN-development board based on the TI CC2430SoC

Benefits

6LoWPAN allows FOR personal area network PAN and sensor actor network applications to connect the local subnet to the whole internet, may it be it IPv6 or IPv4. This is reachable via IPv6 with IPv4-tunneling. Furthermore every single node is reachable and addressable. This is also usable for the internet of things. The whole PAN can get configured and bootstrapped automatically. Remote configuration and maintenance is possible. It can be seamlessly integrated into existing infrastructures.

The protocol stack in combination with the FreeRTOS was found to be highly robust and scalable, so different size of application and networks with differing numbers of nodes are possible. While the IEEE 802.15.4 has been made up for Wireless Personal Area Networks it is often also used in Body Area Networks (BAN) as well. Regarding the usual size of a node it might be even embedded into clothing, e.g. for body monitoring and for AAL and health applications.

SUMMARY

In this paper the applicability of a standardized network protocol-stack for AAL-applications has been reviewed. Its huge capabilities have rendered it fully applicable for sensor- and monitoring-based applications like surveillance of vital-functions, position-tracking, smart-buildings and more.

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