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Radio Standards status

Report

ATJ-kehitysohjelma

”Ajoneuvon / työkoneen langattomat lähiverkot (ALMA)”

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1 Abbreviations

AC	Access Class
AIFS	Arbitration Inter-Frame Space
ASTM	ASTM International (originally American Society for Testing and Materials)
CCH	Control Channel
CW	Contention Window
DSRC	Dedicated Short Range Communications
ECMA	ECMA International (originally European Computer Manufacturers Association)
ETSI	European telecommunications Standards Institution
EU	European Union
IEEE	Institute of Electrical and Electronics Engineers
ISM	Industrial, Scientific and Medical (radio bands)
ITS	Intelligent Transportation Systems
MAC	Medium Access Control (layer)
MIMO	Multiple in, multiple out
OFDM	Orthogonal Frequency-Division Multiplexing
PHY	Physical (layer)
QoS	Quality of Service
SAR	Specific Absorption Rate
SCH	Service Channel
SUN	Smart Utility Network
VANET	Vehicular Ad-hoc Network
V2I	Vehicle to Infrastructure (communication)
V2V	Vehicle to Vehicle (communication)
WAVE	Wireless Access in Vehicular Environment
WBAN	Wireless Body Area Network
WiMAX	Worldwice Interoperability for Microwave Access
WMAN	Wireless Metropolitan Area Network
WPAN	Wireless Personal Area Network
WRAN	Wireless Regional Area Network
6LoWPAN	IPv6 over low power wireless personal area networks

2 Introduction

This report looks into current status of relevant wireless IEEE standards. Possible uses are reliable wireless control bus in working machine environment and non-critical data transmission between working machines. For more profound technical analysis of most of these technologies can be found in Radio Standards and Protocols.

In chapter 3 is summarized some essential IEEE wireless standards and amendments both published and under develoment. Standards are described shortly with their status except draft 802.11p which is descibed in more detail. All approved and published standards can be distiguished by the publication year attached to their names.

In Appendix A standards are presented in sheet format for reference.

3 Status of standards

3.1 WPAN

3.1.1 IEEE std 802.15.6

This project is governed by WPAN task group 6, but is related more to Wireless Body Area Networks (WBANs). The purpose of this standard is to provide an international standard for short range, low power and highly reliable wireless communication for use in close proximity to, or inside, a human body. Specific Absorption Rates (SARs) are considered to keep radiation minimized into the body. Extremely low power and data rates up to 10 Mbps is required. ISM bands and other frequencies approved by national authorities can be used. Current Personal Area Networks do not meet medical and relevant communication regulations for some application environments. [1]

Task group for this standard was formed in November 2007 and its work is currently at open discussion and proposals level. Last published document was minutes from plenary meeting in Montreal, Canada held in May 2009. [2]

3.1.2 IEEE std 802.15.1-2005

This standard specifies MAC and PHY layers of Bluetooth version 1.2. Later versions of Bluetooth will not become future IEEE standards. [3] The standard specifies 1 Mbps of maximum data rate. It uses frequency hopping technique with 79 frequencies channels. Newer Bluetooth specifications up to 2.1 are backward compatible with Bluetooth 1.2. That has data rates theoretically up to 3 Mbps. Bluetooth low energy technology formerly known as Wibree is an additional protocol stack which power consumption is reduced substantially.

3.1.3 IEEE std 802.15.3-2003

This standards primary objective is to offer high data rate communications of about 10 m radius. Low complexity, low cost and low power consumption were desired parameters. Link robustness is important but unlike WLAN it is acceptable for user to move closer to establish it. It operates on 2.4 GHz band and data rate is selectable from 11 Mbps to 55 Mbps.[4]

802.15.3b-2005

This published amendment is for MAC sub layer to support emerging multimedia applications, also lower latency data transfer. [1]

802.15.3c

This is an interesting amendment to the 802.15.3-2003 standard “High Rate Personal Area Networks” for fixed, portable and moving devices. It is a millimeter-wave based alternative physical layer extension especially for multimedia applications. The standard will define a 25 -100 GHz physical layer for higher data rate. Data rates will be at least 1Gbps under normal operating conditions with a typical range no less than 10 meters. [1] According to 802.15.3c unapproved draft D08 dated March 2009 there are 4 channels utilizing frequencies 57.240 –

66.880 GHz, leaving over 2 GHz per channel [5]. That offers superior coexistence than existing 802.15.3 wireless systems.

The amendment has reached Sponsor Ballot 2 of Draft 10 [2].

3.1.4 IEEE std 802.15.4-2006

This standard specifies low rate, ultra low power PHY and MAC layers for WPANs. 2.4GHz and 868/915 MHz bands are specified. Typical protocols include Zigbee and 6LoWPAN, IPv6 over low power wireless personal area networks, or if lower overhead is needed e.g. nanoIP could be used.

802.15.4a-2007

This published amendment specifies alternate PHYs low-rate WPANs, a Chirp Spread Spectrum (CSS) and Ultra Wide Band (UWB) solutions. Impovements are precision ranging, communications range, robustness and mobility. No further amendments are under development at the moment. [1]

CSS is operated at 2.4 GHz band and UWB at bands 250 – 750 MHz, 3.1 – 4.8 GHz and 6,0 – 10.6 GHz. Standard offers data rates up to 1 Mbps. Nanoloc radios by Nanotron Technologies can reach up to 2 mbps [6].

802.15.4e

This amendment provides enhancements to MAC: TDMA, channel hopping, improved CSMA, asymmetrical keys in security and low latency for control applications. Functionality facilitates industrial applications (such as addressed by HART 7 and the ISA100 proposed standards). [1] Task group 4e has defined the application spaces that it will address along with the MAC behavior changes/additions that are required to enable those application spaces. [7]

802.15.4f

This amendment provides for low cost, ultra low energy consumption, flexible and highly reliable communication means and air interface protocol for Active RFID and sensor applications. The air interface supports a wide range of needs for active RFID systems and enable improved performance and flexibility for mass deployments of active RFID systems around the world. [1] Call for PHY proposals for the next task group meeting is active [8].

802.15.4g

This work group creates an alternate PHY layer for Smart Utility Networks (SUN), large scale process control for geographically diverse environments. Much larger frames up to mimimum of 1500 octets. Operation in any of the regionally available license exempt frequency bands, such as 700MHz to 1GHz, and the 2.4 GHz band. Networks can grow potentially to millions of fixed endpoints. [1] Call for proposals was issued in January 2009 and presented in March plenary meeting.Call for applications was issued in February 2009 and 22 final proposals were presented to task group in May. [9]

3.1.5 ECMA-368/9 (2008)

IEEE 802.15.3a task group was set to create UWB standard and it had two mutually exclusive architecture proposals on the table, one supported by WiMedia Allliances and another by UWB Forum. Since the situation was in deadlock the task group was disbanded in January 2006. WiMedia Allliance's proposal was standardized as ECMA standard in December 2005. [10]

WiMedia Alliance's UWB radio platform is described in ECMA-368 and the MAC-PHY interface for it is described in ECMA-369. Both standards have reached third edition in December 2008 only with some editorial changes [11,12]. Standards were approved as ISO/IEC standards in 2007 [13,14]. ETSI has published ECMA-368 as ETSI TS 102 455 V1.1.1 in January 2006 [15].

Data rates theoritically up to 480 Mbps for short ranges are supported. Practically conforming devices should reach maximum data rate of 200 Mbps. 14 sub bands 528 MHz each can be used. [11,14]

3.2 WLAN

3.2.1 IEEE Std 802.11-2007

This standard incorporates amendments 1 through 8 including e.g. a, b, g, and corrections and clarifications to the 802.11 standard.

802.11n

This amendment will define standardized modifications to both the 802.11 PHY and the 802.11 MAC layer with a maximum throughput of at least 100 Mbps [1]. It will implement MIMO-OFDM at 2.4 and 5 GHz. Better range is provided by multiple antennas and 5 GHz band offers less radio interference than crowded 2.4 GHz.

Latest draft is recirculation draft 10.0 which has reached IEEE-SA sponsor ballots and is dated 15.5.2009. The standard IEEE 802.11n is to be published in November 2009 [16].

802.11p

Amendment 802.11p is a technique for Vehicular Ad-Hoc networks (VANET). 802.11 task group p will define enhancements to 802.11 required to support Intelligent Transportation Systems (ITS) applications in high-speed vehicle environment.

At the moment latest draft of standard 802.11p is work group letter ballot recirculation draft 6.0 dated 31.3.2009. According to 802.11 official timelines this amendment should be published in June 2010. [16]

This amendment is based on ASTM E2213-03: "*Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems - 5.9 GHz Band Wireless Access in Vehicular Environments (WAVE) / Dedicated Short Range*

Communications (DSRC) Medium Access Control (MAC) and Physical Layer (PHY) Specifications". [17]

WAVE uses 802.11a with modifications for adapting it to be suitable in vehicular environments, association/authentication, usage of specific transmit power and of multiple channels with different bandwidth per channel than defined in the IEEE 802.11a standard. Basic algorithms and modulation schemes are unchanged.

WAVE is a mode of operation for use by IEEE Std 802.11 devices in environments where the physical layer properties are rapidly changing and where very short-duration communications exchanges are required. Wireless communication in vehicular environment takes place in potentially rapidly changing communications environments and in situations where transactions must be completed in time frames much shorter than the minimum possible with infrastructure or ad hoc 802.11 networks. [18]

WAVE utilizes upper 5 GHz band. Frequencies originally planned for North America but later EU also reserved 5.9 GHz band for vehicle applications. Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication are possible up to 1000 meters distances while operating at speeds up to a minimum of 200 km/h. [1]

Channel coordination

Channel access in WAVE is contention based. User priority uses the IEEE 802.11e Enhanced Distributed channel Access (EDCA) mechanism [19].

One channel is used at a time so stations have to alternate between Control Channel (CCH), one of the Service Channels (SCHs), or safety channel. Application messages are categorized into different Access Classes (ACs), or priorities, for channel access. AC0 is the lowest and AC3 is the highest priority and there’s a packet queue for each as seen in fig. 1

User priority works so that AC’s are given individual Arbitration Inter-Frame Space (AIFS), a minimum time interval between wireless medium becoming idle and the start of transmission frame. Contention Window (CW) is an interval from which a random number is drawn to implement the random back-off mechanism. For the first attempt a random selection between 0 and CW_{min} is committed. So user backs off for a while before new attempt. If channel is accessed Transmit Opportunity (TXOP) can limit the time duration for which a station can transmit. If channel is not accessed, station can keep trying until both CW_{max} (fig. 2) and maximum number of tries is reached. Low priority transmissions will have longest wait times as seen in fig. 3.

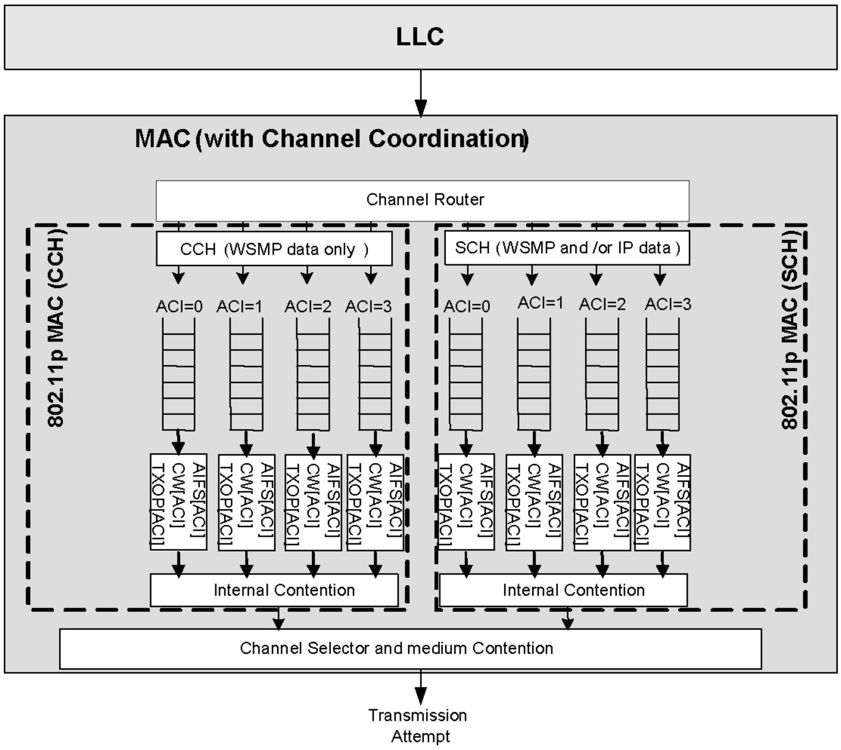

Fig. 1. An example of WAVE MAC with channel coordination [19].

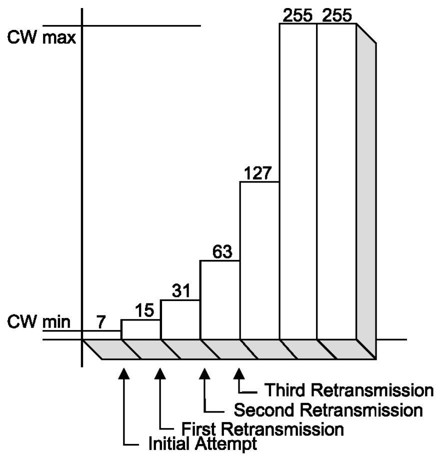

Fig. 2. An example of exponential increase of CW [20].

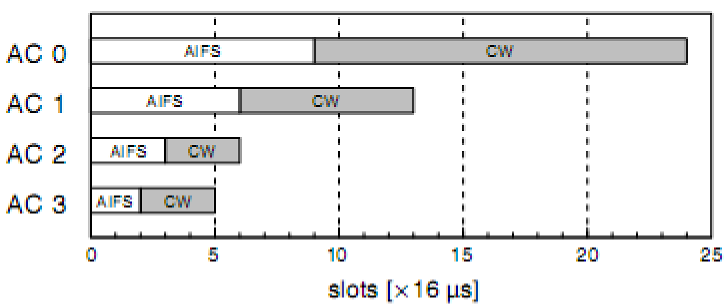

Fig. 3. Wait times for the access categories caused by contention in WAVE [21].

The operational environment of WAVE is demanding. Very short latencies are required, and some applications must complete multiple data exchanges within 4 to 50 ms [1]. That sets high requirements for the channel access and packet queues. Some reports show that in simulations where increasing number of nodes sending high priority messages, collision probability increases significantly [21,22]. That may prevent distribution of time critical messages. In fig. 4 is showed the effect of low CW sizes, meaning high priority packets are being sent, with increasing number of nodes. The probability for collision free channel decreases dramatically.

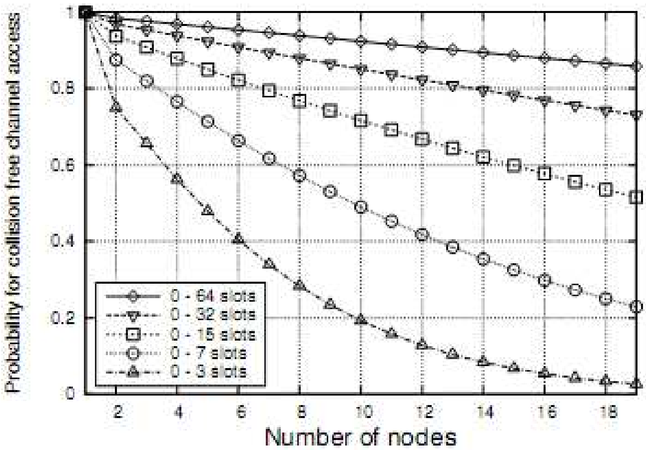

Fig. 4. Probability for a collision-free channel access for different CW sizes [21].

Related protocols

Upper layer protocols for the WAVE architecture are:

- IEEE std 1609.1-2006 “Resource Manager”
- IEEE std 1609.2-2006 “Security Services for Applications and Management Messages”
- IEEE std 1609.3-2007 “Networking Services”
- IEEE std 1609.4-2006 “Multi-channel Operation” (MAC extension layer to WAVE)

3.3 WMAN

3.3.1 IEEE std 802.16-2009

In this standard is defined worldwide multivendor interoperable wireless access of fixed and mobile point-to-multipoint broadband wireless access. MAC is structured to support multiple PHY specifications. In May 2009 802.16-2004 has been updated to 802.16-2009 and most amendments have been rolled up under the same standard including e.g. 802.16e Mobile WiMAX.

3.3.2 IEEE std 802.20-2008

Mobile broadband wireless system using licensed bands under 3.5 GHz. Peak data rates per user are excess of 1 Mbps. It has support for vehicular mobility. It has two operating modes which both have their own PHY and MAC layers. One mode is supporting 625 KHz multi carrier mode and one wideband. [1,23]

4 Conclusions

There are some standards that might be suitable for reliable low delay control bus over short ranges.
IEEE 802.15.1 is designed for consumer electronics as mobile phones, digital cameras etc. Frequency hopping provides some protection from interference and allows better use of limited band. Range can be expanded by higher transmit power from few meters to nearly hundred. Nonetheless it is not optimized for reliable low delay transmissions.

802.15.4 is designed for low power low data rate technology sensor networks. The standard is however being upgraded, the 802.15.4e amendment e.g. is concentrating on industrial applications and high reliability control networks. It offers better tolerance for interference and low latency. But that amendment may take some time to finish.
802.15.4a is designed to be robust radio technology in demanding environments. Both CSS and UWB physical layers are unsensitive for radio interference and multipath fading. UWB offers much better coexistence than other 802.15.4 technologies which operate at 2.4 GHz band.

High rate WPANs, 802.15.3 and ECMA-368/9, are designed for neither high reliability-low latency nor long range use. Their main use is in short range multimedia applications. Although 802.15.3b offers some minor optimizations in latency etc. and ECMA-368 utilizes UWB technology which has good interference tolerance.

Communication between machines requires range, data rate and sometimes less strict link reliability. In the 802.11 technologies, communication range is lucratively combined with high data rate. 802.11p is a very interesting possibility with ranges up to 1 km, however it will not be published until a year or so from now.

WMAN technologies are designed for operator networks. Range is good but licensed bands and operator access points are used.

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9 Institute of Electronics and Electrical Engineering, IEEE 802.15.4 TG4g public page, http://www.ieee802.org/15/pub/TG4g.html
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Appendix A: wireless standards reference sheets

WPAN

Standard (-year, if approved)	Frequency	Bandwidth	Bitrate	Range (approx.)	Bandwidth efficiency	Modulation
IEEE 802.15.6*	ISM + others		<= 10 Mbps	Inside or vicinity of body		
IEEE 802.15.1-2005	2,4 GHz	1 MHz	1 Mbps	10 m (<100 m)	1 bps/Hz	GFSK
IEEE 802.15.3-2003	2,4 GHz	15 MHz	11 to 55 Mbps	<100 m	<=3,7 bps/Hz	QPSK, DQPSK, 16/32/64-QAM
IEEE 802.15.3C	57-64 GHz	2,16 GHz	>= 1 Gbps	10 m		π/2 BPSK, π/2 QPSK, 8-π/2 QPSK, 16-QAM
IEEE 802.15.4-2006	2,4 GHz 868 MHz	5 MHz	250 kbps 20 kbps	<100 m	0,125 bps/Hz	O-QPSK
IEEE 802.15.4a-2007 CSS	2,4 GHz	20 MHz, for ranging 80 MHz	1000 kbps	<100 m	0,045 bps/Hz	DQPSK-DQCSK
IEEE 802.15.4a-2007 LR UWB	250-750 MHz 3,1-4,8 GHz 6,0-10,6 GHz	500 MHz 1000 MHz 1300 MHz	851 kbps 110 kbps 6,81 Mbps 27,24 Mbps	<100 m	0,002 bps/MHz	BPM-BPSK
ECMA-368:2007 ECMA-369:2007 (ISO/IEC 26907:2007 ISO/IEC 26908:2007)	3,1-10,6 GHz	528 MHz	<= 480 Mbps	<10 m	<=0,9 bps/Hz	MB-OFDM

*IEEE 802.15.6 can be considered also as Wireless Body Area Network (WBAN).

WLAN

Standard (-year, if approved)	Frequency	Bandwidth	Bitrate	Range (approx.)	Bandwidth efficiency	Modulation
802.11a-1999*	5 GHz	20 MHz	54 Mbps	100 m	2,7 bps/Hz	OFDM, BPSK, QPSK, 16QAM, 64QAM
802.11b-1999*	2,4 GHz	20 MHz	11 Mbps	100 m	0,55 bps/Hz	DSSS, BPSK, QPSK, CCK
802.11g-2003*	2,4 GHz	20 MHz	54 Mbps	100 m	2,7 bps/Hz	OFDM, BPSK, QPSK, 16QAM, 64QAM
802.11n	2,4/5 GHz	40 MHz	150 Mbps and higher	160 m	3,7 bps/Hz	OFDM
802.11p	5,9 GHz (5,8 GHz)	10 MHz	?	<= 1000 m	?	OFDM

*amendments a, b, g along others are rolled up in same standard, 802.11-2007.

WMAN

Standard (-year, if approved)	Frequency	Bandwidth	Bitrate	Range (approx.)	Bandwidth efficiency	Modulation
802.16-2004 (superseded) 802.16-2009*	10-66 GHz <11 GHz 5-6 GHz	28 MHz	134 Mbps	5 km	4,5 bps/Hz	QPSK, 16QAM, 64QAM
802.16a-2003	2-11 GHz	20 MHz	75 Mbps	10 km	3,7 bps/Hz	BPSK, QPSK, 16QAM, 64QAM, OFDM
802.16d	2-11 GHz	25 MHz	75 Mbps	8 km	3 bps/Hz	BPSK, QPSK, 16QAM, 64QAM
802.16e-2005	2-6 GHz	20 MHz	30 Mbps	5 km	1,1 bps/Hz	BPSK, QPSK, 16QAM, 64QAM, OFDM
802.20-2008	<3,5 GHz	625 kHz, Wideband	1024 (down) / 300(up) kbbps	6 km	1,0 bps/Hz	OFDM, 24/32/64-QAM

*802.16-2009 includes a, d and e amendments.