Review of Power Line Communications Standards in Africa

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Abstract. The standards in power line communications (PLC) calibrate parameters such as frequencies allocation, signal level, security, topology of the network and many others parameters. The leap forward of power line communications technology is motivated by the willingness of the standardization organizations (SDO)s such as ITU, IEC, ISO, IEEE, CENELEC to define how the technologies are going to be deployed. This paper presents the different SDOs, Alliances and groups regulating the PLC sector. The interoperability and coexistence for some technologies are underlined. The process of developing PLC standards by ITU, IEEE 1901, CENELEC is described. The advantages and disadvantages of using PLC technology in Africa are discussed.

Keywords: Standards · SDOs · Alliances · Technologies · PLC · Communication · Frequency

1 Introduction

To provide efficient transparent communication over the power line network, standards are fundamental. A standard is a document providing rules requirements and guidelines for a product, process and services [1, 2]. The document is prepared and produced by the standardization organizations (SDOs). In power line communications (PLC), the SDOs focus on the physical (PHY) and on the data link (DLL) layers as shown on Fig. 1. The other layers are reserved for the application. The power line communications technology shares some regulations with the wired based communication technologies such as telephone wire.

Power line communications is characterized by two regulated segments named narrow band power line communications (NBPLC) and broad band power line communications (BBPLC). BBPLC deals with frequencies above 1 MHz while NBPLC deals with frequencies less than 500 kHz. The range of frequencies between 3 kHz and 145.8 kHz is regulated by the European committee for electrotechnical standardization (CENELEC) [3, 4]. It is suitable for low data transmission over power line. It is possible to deploy high data transmission over NBPLC in the range of frequencies between 145.3 kHz and 478.125 kHz, which corresponds to the second frequency band of the federal communication commission (FCC) [5]. This paper presents in Sect. 2 the repartition of the frequencies between SDOs. Forthwith, some applications of power line communications for both NBPLC and BBPLC are

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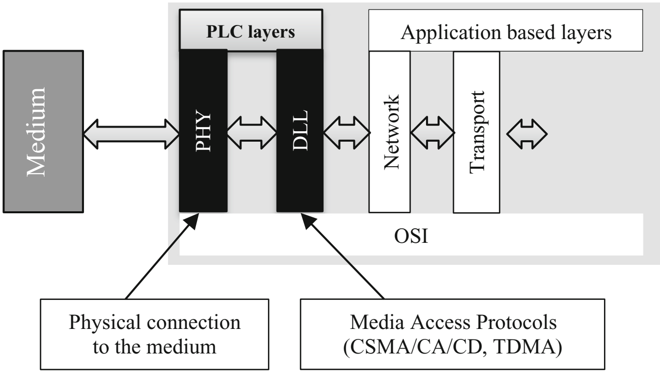
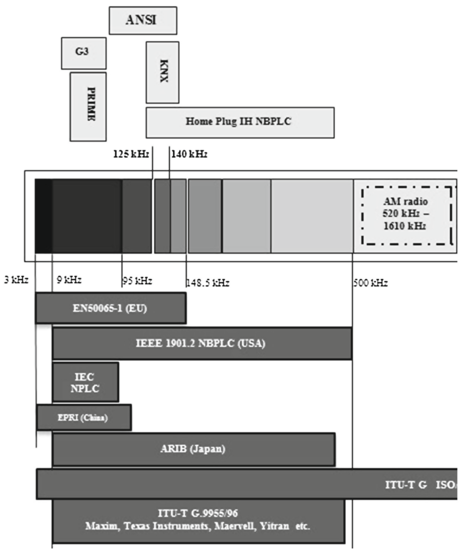


Fig. 1. Illustration of the PLC layers

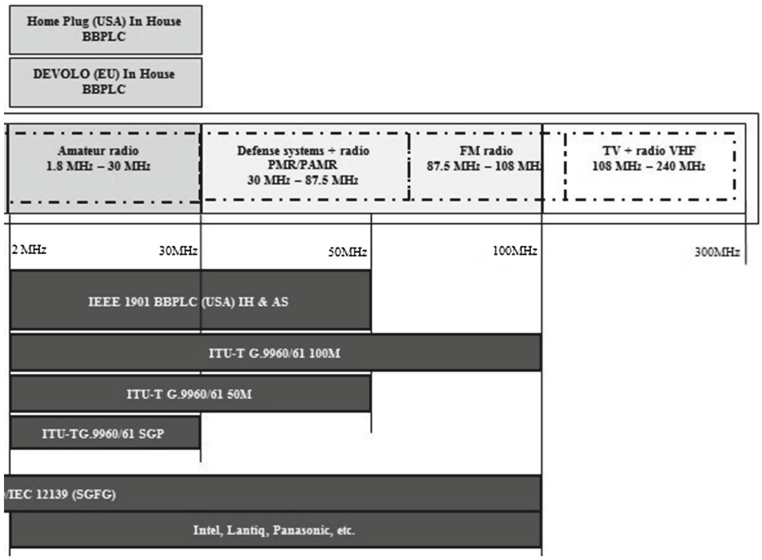
presented in Sect. 3. The Sect. 4 talks about coexistence of standards and interoperability between technologies. Section 5 gives the advantages and disadvantages of PLC technology in African context.

2 Frequency Allocation Chart

The international telecommunication union (ITU), the international organization for standardization (ISO), the international electrotechnical commission (IEC), the institute of electrical and electronics engineers (IEEE) and CENELEC are the main SDOs that develop and propose standards in communication sector. G3-PLC, Powerline intelligent metering evolution (PRIME), the american national standards institute (ANSI), KNX and HOMEPLUG are some groups and alliances that develop and deploy standards and technologies in power line communications sector. These SDOs, groups and alliances are characterized by their frequency band. Some work on NBPLC while others are on BBPLC. SDOs such as IEEE and ITU are proposing standards and technologies for both NBPLC and BBPLC. The authors analyzed the frequency band of each SDO and alliance and the summary of the bands occupied are presented on Fig. 2. The IEEE organization proposes for NBPLC to work in the range of frequencies between 9 kHz and 500 kHz [6]. The ITU organization works on the range of frequencies from 3 kHz to 490 kHz, while CENELEC proposes the frequencies between 3 kHz and 148.5 kHz. Over BBPLC, IEEE works on the range of frequencies between 2 MHz and 50 MHz while the ITU organization proposes a wider range of frequencies: from 2 MHz to 100 MHz [7, 8]. The CENELEC organization does not work on BBPLC [2, 9]. G3-PLC, PRIME, ANSI and KNX propose technologies using the CENELEC's frequency bands. G3-PLC works on the range between 35 kHz–90 kHz while PRIME alliance uses the frequency band 42 kHz–90 kHz. ANSI proposes technologies for the frequencies from 86 kHz–131 kHz and KNX works with the band of frequencies between 125 kHz to 140 kHz [10]. HomePlug is present over the whole PLC's frequency band. It proposes HomePlug Green PHY (HPGH NB), standards and technologies over narrow band occupying the



a Frequencies between 3 kHzand 2 MHz



b Frequencies between 2 MHzand 300 MHz

Fig. 2. Power line communications frequencies allocation by SDOs, alliances and groups

range of frequencies between 120 kHz and 400 kHz. HomePlug also proposes HomePlug Green PHY (HPGP BB) and HomePlug AV (HPAV) using the frequency band 1.8 MHz to 30 MHz [11]. HomePlug AV2 technologies extends the HPAV's frequencies to 86 MHz [10, 12]. HPGP BB differs from HPAV on the modulation schemes used, the forward error correction (FEC) methods and the access modes [10].

The IEEE 1901-2010 standard uses the frequencies between 2 MHz and 50 MHz. The IEEE 1901.2 provides standards for low frequency, less than 500 kHz, narrow band power line communications for smart grid applications. Its uses the frequency band 10 kHz–490 kHz for low and high data transmission [6]. The ITU organization separates standards for the physical layer (PHY) and for the data link layer (DLL). It proposes a technology named ITU-T G.hnem for NBPLC. The ITU-T G.9955 standard specifies the regulations for PHY while the ITU-T G.9956 standard gives rules for DLL [8]. The technology proposed by the ITU organization on BBPLC is ITU-T G.hnem. The ITU-T G.hnem complies with two different standards: The ITU-T G.9960 standard developed for PHY layer and the ITU-T G.9961 standard proposed for DLL. The ITU organization on BBPLC specifies a platform for smart grid (2 MHz to 30 MHz), it also gives specifications to differentiate between two cases: when the distance between two modules is greater than 50 m (2 MHz to 50 MHz) and when the distance is greater than 100 m (2 MHz to 100 MHz) [8]. The CENELEC organization is composed of many technical bodies. One of them is in charge of developing EN50065-1 standard (Signaling on low-voltage electrical installations in the frequency range 3 kHz to 148.5 kHz - Part 1: General requirements, frequency bands and electromagnetic disturbances) [3, 4]. The EN50065-1 standard divides its frequency band in 4 sub-bands [3, 4]: CENELEC-A (3 kHz–95 kHz), reserved exclusively for energy providers, and respectively CENELEC B-C-D (95 kHz–125 kHz; 125 kHz–140 kHz and 140 kHz–148.5 kHz). The CENELEC B-C-D sub-bands are opened for end user applications. The 2010's version of the EN50065-1 is superseded by the EN50065-1: 2011. The EN50065-1: 2011 standard was ratified on 2011-03-21; it was available on 2011-04-22, announced on 2011-09-21 and published on 2012-03-21 [13].

The CENELEC organization shares some information with the international electrotechnical commission (IEC), with the european committee for standardization (CEN) and with the european telecommunication standards institute (ETSI). Some PLC's projects under IEC are developed in collaboration with the international organization for standardization (ISO).

The IEC NBPLC's standards propose to work between 3 kHz and 76 kHz [6]. The special international committee on radio interference (CISPR) acting under IEC gives the limits of the interferences. The disturbances limits for PLC systems are defined by the CISPR22 standard. The electric power research institute (EPRI) organization in China prefers the range between 3 kHz and 90 kHz while the FCC organization in USA works over the range from 10 kHz to 490 kHz [14]. The association of radio industries and businesses (ARIB) organization in Japan proposes the ARIB STD – TB4 standard, using the range between 10 kHz and 450 kHz. In Canada, the interference causing equipment standard (ICES) proposes ICES – 006 standards working in the range of frequencies between 0 and 535 kHz [15]. The transmission level for all the standards is compatible with the graph proposed on Fig. 3. It is proposed by the CENELEC and the FCC organizations [3, 4]. In NBPLC frequency bands, the ITU-T G.hnem and the IEEE P1901.2 technologies, ANSI, HomePlug, PRIME, ISO and IEC use the signal level proposed in EN50065-1 by the CENELEC organization, they use FCC's signal level when the frequency is out of the CENELEC's range of frequencies. In certain applications, the IEC standards use exclusively the CENELEC's

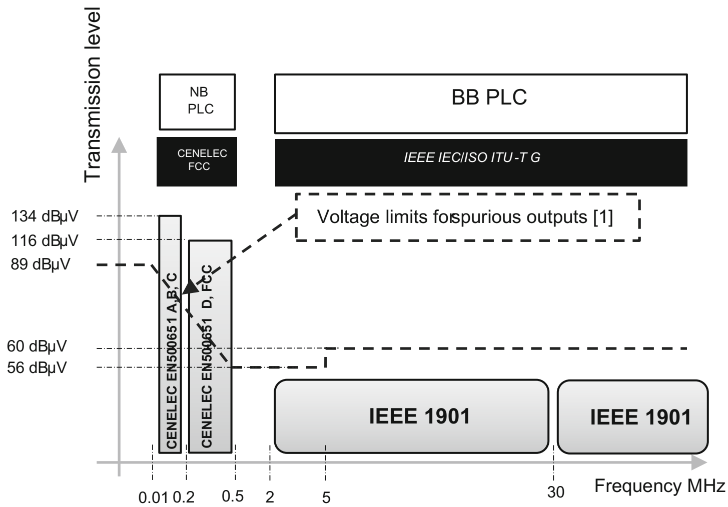


Fig. 3. Transmission level spurious output [3, 4]

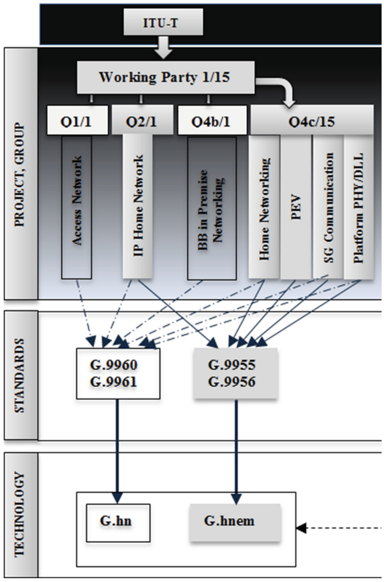
transmission level. The standards' elaboration methods within the main IDOs were analysed by the authors and the summary is presented on Fig. 4.

3 Applications of Power Line Communications

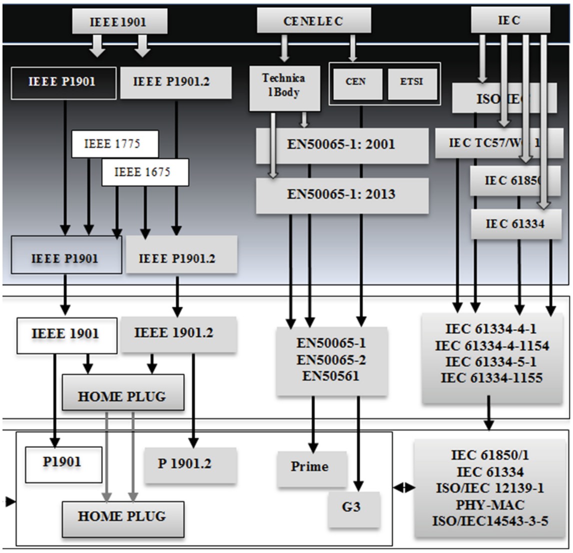
The applications of power line communications technologies cover the whole axis of frequencies proposed in Fig. 2. In accordance with the application, the axis is divided into three portions as indicated in Fig. 5. Any portion is suitable for some specific applications.

The broad band PLC uses the frequency band between 1 MHz and 300 MHz. It is suitable for high data rate transmission, more than 10 Mbps. The NBPLC's portion uses the CENELEC bands for low data rate transmission, less than 50 kbps. Over the frequencies from 145.3 kHz to 500 kHz, the NBPLC's technologies are used to perform high data rate transmission between 50 kbps and 1 Mbps. Thereby, the applications of the power line communications technology are related to the frequency band used. The applications of BBPLC can not be deployed over NBPLC frequencies. The deployment of the technology over each range of frequencies is supported by many companies and organisations. Table 1 gives some specifications on the application of the power line communications technology. It shows the frequency band, some modulation schemes proposed by the SDOs for both NBPLC and BBPLC. The complexity of the forward error correction (FEC), the access method and some companies and organisations supporting the standards are also mentioned.

The NBPLC frequency bands are used for metering, lighting, energy and grid management.



a: Building up for ITU-T G.hn and G.hnem



b: Building up for IEEE1901, CENELEC and IEC

Fig. 4. PLC standards building up

The BBPLC frequency band is used for applications such as last mile telecom, voice over IP and high definition television. Companies such as Gorlitz and alliances such as G3-PLC, PRIME are specialised in meter manufacturing. The KNX organisation is the standard for home and building control.

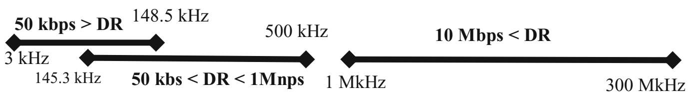


Fig. 5. Data rate (DR) repartition over PLC frequencies

Table 1. Applications of PLC [6, 9, 12, 15, 16]

	NBPLC		BBPLC
	Low data rate	High data rate	High data rate
frequency	3 – 148.5 kHz	145.3 – 478.125kHz	1 MHz–300 MHz
Modulation and coding	FSK , BPSK, FFH (Fast frequency hopping), SFSK (dual ch/spread FSK), DCSK diff chirp shift keying	DBPSK, DQPSK, OFDM MCM multiple carrier modulation	MCM/COFDM Bit loading
FEC	Low complexity and reliability *(RS + Convolutional)*	Strong, high reliability designed *(RS + Convolutional, Differential coding)*	Medium Maximum throughput *(Convolutional Turbo Code CTC for FFT Concatenated Reed-Solomon and Convolutional code for WAVELET)*
Access	CSMA/CA TDMA	CSMA/CA TDMA	CSMA/CA TDMA
Transport layer	IPv6, IPv4, Ethernet I EC62056	IPv6, IPv4, Ethernet I EC62056	IPv6
Application	Automatic Meter AMR Power Line Area Network	Airfield lighting, Energy management, Smart Grid application and metering, AMR/AMR	Last Mile Telecom (LMT}, Internet, VoIP, IH networking, High definition TV (HDTV) …
Companies and organisations	Bush Jaeger, Echelon, Gorlitz, Ytran, Renesos, AMI solution, Landis&Gyr …	ADD Grup, iAd, Maxim, PRIME, landis&Gyr, G3, ANSY, STMicroelectronic, Usyscom, Ziv , Philips KNX…	Amperiom, Current, DS2, Home plug, Mitsubishi, OPERA, Panasonic, Spidcom, Devolo…

4 Interoperability and Coexistence

This section presents the practical issue related to the deployment of standards and technologies in power line communications sector. What are the standards and technologies that can work together in the same network and in the same frequency band? The ITU organisation has developed the inter system protocol (ISP) scheme named ITU-T G.9972. The ITU-T G.9972 standard allows at least four technologies simultaneously [10]. The recommendations of ITU were accepted by some other organisations such as IEEE. The IEEE organisation has developed the IEEE 2030 standard for smart grid interoperability. The IEEE 1901.2 devices integrate the interoperability option for PRIME and G3 legacy specifications. Those devices must implement CENELEC A band [16].

The coexistence must be seen as the ability of more than one technology, network, system or device to exchange data and to be able to use the information exchanged.

In NBPLC frequency bands, technologies must develop mechanism to coexist with other narrow band technologies. The ITU-T G.9972 standard developed by the ITU organisation is in compliance with the coexistence as defined above. Within the IEEE organisation, the compliance and interoperability working group work (C & I WG) discusses the same issue. HomePlug alliance complies with the rules and regulations of coexistence and interoperability defined by C & IWG. It produces technologies and products that coexist and interoperate with other standards. This shows that the IEEE organisation complies with the recommendation acts G.9972 of the ITU organisation.

5 PLC Technology in African Context

The ITU organisation divides the world's communication by regions. Africa falls under ITU region I. Therefore, african countries align their frequency allocations with those specified for ITU region I [17]. In South Africa, the radio communication regulations are required by the electrical contractors association (ECA). It is compulsory for the companies proposing services to comply with the telecommunication laws. They must also comply with the rules and regulations of the independent communications authority of South Africa (ICASA). The african organisations look at a PLC's cost effective networking for the grid. Most of the devices are based on the Homeplug PLC standards, allowing different devices from different manufacturers to talk to each other. Companies such as INOVATECH are proposing high speed power line communications (HSPLC) services. They propose solutions for energy management such as real time monitoring, detection, measurement and waveform capture, remote automation and support for prepaid. Nexans proposes solutions for smart grid applications. In Ghana, CACTEL, the United Kingdom PLC's company carried out a series of communication demonstration over power lines. The tests were performed in collaboration with the telecommunication company and the electricity company of Ghana. CACTEL has successfully demonstrated the use of an automated meter reading (AMR) technology [18]. Goal technology solutions (GTS) is spreading power line communications technologies over the african countries such as South Africa, Uganda and Kenya. This shows that PLC in Africa is under way.

6 Conclusion

The description and the presentation of the standards governing power line communications technology was the purpose of this paper. The main SDOs were presented for both NBPLC and BBPLC frequency bands. The standard building up was also presented for the main SDOs. Some lines were written on the applications of power line communications technology. One point discussed the coexistence and the interoperability of several technologies. It is important to emphasise the fact that, even with the plethora of standards leading power line communications, there is still a gap. The effectiveness of the coexistence and the interoperability between technologies needs to be taken into serious consideration by the standardisation organisations and alliances. It is also very important for the manufacturers to comply with the CISPR limits. Africa was presented as the late comer in the power line communications area. The products proposed to the african countries are usually developed under others countries' regulations given the fact that the manufacturers are not based in Africa. It is then fundamental to rise in Africa organisations such as the south african radio league (SARL) to adapt international regulations to the african context.

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