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Powerline Telecommunications (PLT);
Powerline communication recommendations for smart metering and home automation

Reference

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Powerline Telecommunications (PLT).

1 Scope

The present document concentrates on recommendations for power line communication for smart meters and home automation using IP based transports along with DLMS/COSEM data models.

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] CENELEC EN 50065-1: "Signalling on low-voltage electrical installations in the frequency range 3 kHz to 148,5 kHz - Part 1: General requirements, frequency bands and electromagnetic disturbances".

[i.2] Recommendation ITU-T G.9972: "Coexistence mechanism for wireline home networking transceivers".

[i.3] IEC 62056-47: "Electricity metering - Data exchange for meter reading, tariff and load control - Part 47: COSEM transport layers for IPv4 networks".

[i.4] IEEE 802.15.4™: "IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 15.4: Wireless Medium Access Control (MAC) and Physical Layer (PHY) Specifications for Low Rate Wireless Personal Area Networks (WPANs)".

[i.5] Recommendation ITU-T G.993.2: "VDSL2 :Very High Speed Digital Subcriber Line transceivers 2".

[i.6] Recommendation ITU-T G.9903: "Narrowband Orthogonal Frequency Division Multiplexing Power Line Communication Transceivers for G3-PLC Networks".

[i.7] Recommendation ITU-T G.9904: "Narrowband orthogonal frequency division multiplexing power line communication transceivers for PRIME networks".

[i.8] IEEE 1901.2™ - 2013: "IEEE Standard for Low-Frequency (less than 500kHz) Narrowband Power Line Communications for Smart grid Applications".

[i.9] IEEE 1901™ - 2010: "IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications".

[i.10] HomePlug Green PHY™ Specification.

NOTE: See http://www.homeplug.org/tech/homeplug_gp.

[i.11] ETSI TS 102 578: "PowerLine Telecommunications (PLT); Coexistence between PLT Modems and Short Wave Radio broadcasting services".

[i.12] IETF RFC 4919: "IPv6 over Low-Power Wireless Personal Area Networks (6LoWPANs): Overview, Assumptions, Problem Statement, and Goals".

[i.13] IETF RFC 4944: "Transmission of IPv6 Packets over IEEE 802.15.4 Networks".

[i.14] ISO/IEC 14908-3: "Information technology -- Control network protocol -- Part 3: Power line channel specification".

[i.15] Recommendation ITU-T G.9901: "Narrowband Orthogonal Frequency Division Multiplexing Power Line Communication Transceivers - Power Spectral Density Specification".

[i.16] Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of ecodesign requirements for energy-using products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council.

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

Data Link Layer (DLL): (e.g. media access control or MAC) is where the exchange of frames (many bits) is performed

NOTE: The network layer is the level where paths are determined and logical addressing is applied for packets (many frames). End-to-end connections are formed at the transport layer and segments (many packets) are exchanged. The session layer deals with interhost communication. The presentation layer deals with data representation and encryption. Finally, the application layer is the level at which interaction with a user is attained. Sometimes technologies will use a different model from the seven layers of the OSI stack. These models may only reference three or four layers: however the functionality of all seven OSI layers is typically bundled in to the model regardless. The OSI model is generally accepted as the most detailed practical representation of communication functionality.

Home Area Networks (HAN): sometimes referred to as a Premise Area Network (PAN) or a Building Area Network (BAN), is an application specific LAN, which includes devices within a single premise (industrial site, commercial business or home) communicating over one or more networks.

NOTE: Electric utilities are looking to leverage these networks to provide relief during high demand periods (demand response) by communicating through some type of home gateway bridging utility and home networks. Internet service providers are looking to provide revenue generating services using home automation networks.

Home System (HS): is an interconnection of functional devices as:

- Energy Meter;
- Local Display;
- Demand Response device and
- Local application server.

Local Area Networks (LAN): this zone identifies a "close" set of devices in communication, as the name implies, in a local configuration

NOTE: Often each floor of a building may be on its own LAN, or a single server room may be a LAN.

RPL: IPv6 Routing Protocol for Low-Power and Lossy Networks

smart energy meter: is a device to measure the energy consumption data and make these data available for Smart service provider and the local application server, mostly operating in two way communications device in reliable manner with a set of management functions

NOTE: All communications are generally encrypted and provide real time or near real time measurements to the local application server.

Smart Grid (SG): smart grid is achieved by overlaying the power systems infrastructure with communications infrastructure

NOTE: Benefits are derived by delineating the communications infrastructure along functions that are not quite tied on a one-to-one basis with the power system infrastructure.

The Physical layer (or PHY layer): physical layer is the transmission of data at the bits levels from the signal processing extracted from electrical lines media

use case: description of a specific configuration/deployment scenario of a system from the user point of view

NOTE: The user consider the system as a blackbox and he perceive from the outside the system from the interactions and responses.

Wide Area Networks (WAN): this zone is the bridge between FANs and SANs and the utility LAN and back office

NOTE: This includes communications from control centres to the substations. This is commonly referred to as 'backhaul' communications.

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

6LowPAN	IPv6 Low Power Wireless Personal Area Network
CE	Consumer Electronics
CFL	Compact Fluorescent Lights
COSEM	Companion Specification for Energy Metering
DLL	Data Link Layer
DLMS	Device Language Message Specification
DRM	Digital Radio Mondiale
EC	European Commission
EMC	Electro Magnetic Compatibility
EN	European Norm
ESNA	Energy Services Network Association
FAN	Field Area Network
FFT	Fast Fourier Transform
GFCI	Ground Fault Circuit Interrupter
HAN	Home Area network
IEC	International Electrotechnical Commission
IHD	In Home Displays
IP	Internet Protocol
IPTV	Internet Protocol based Television
ISP	Internet Service Provider
LAN	Local Area Network
M2M	Machine to Machine
MAC	Media Access Control
MDU	Multi Dwelling Units
MTBF	Mean Time Between Failures
OFDM	Orthogonal Frequency Division Multiplex

OSI	Open System Interconnection
PHY	Physical layer
PLC	Power Line Communications
RCCB	Residual-Current Circuit Breaker
SAN	Sensor Area Network
TCP	Transmission Control Protocol
UDP	User Datagram Protocol

4 Recommendations for functionalities

4.1 List of functionalities

Smart Meters are designed for utilities (electricity, gas, water and heating) which are able to base their bills and meter readings on accurate consumption provided by the meter's interface.

Smart Metering provides also information to:

- the customer on request for energy saving and the home gateway propose decisions on their energy usage;
- energy suppliers to understand their customer energy usage and services;
- distributors for monitoring the energy usage and network management; and
- monitoring the customer generating their own electricity for the financial reward on the final billing.

4.2 List of additional functionalities

The proposed list of 6 main additional functionalities is set out below. The functionalities have been expressed in broad terms Identifying functionalities at high level will permit flexibility, innovation and competition.

F1. Remote reading of metrological register(s) and provision to designated market organisation(s).

F2. Two-way communication between the metering system and designated market organisation(s).

F3. Meter supporting advanced tariffing and payment systems.

F4. Meter allowing remote disablement and enablement of supply.

F5. Two way communication data passive interface with (and where appropriate directly controlling) individual devices within the home/building.

F6. Meter providing information via portal/gateway to an in-home/building display or auxiliary equipment.

F7. Monitoring for electricity theft.

F8. Meter providing power quality data and alarms.

4.3 Home automation

Home automation and energy management systems need to get information on consumption data from smart meters. In Home Displays (IHD) (including smart phones and laptops) are designed to show actual load demand to customers. To enable open application support to these use cases, a passive data interface is defined to the smart energy meter and the M2M gateway where home automation gateways can connect and get data. This method enables different kinds of home automation systems and energy management technologies to connect to smart meters using a standardized interface. Home automation and energy management gateways can have communication to M2M gateways or smart energy meters.

"Passive" means here that it is not be possible to inadmissibly affect the operation and the metrology of the smart energy meter/M2M gateway, in particular any legally relevant function.

The main issues are:

- interface to smart home architecture;
- open communication protocol;
- home displays;
- TCP/IP or UDP/IP enabled machines;
- "one-to-many" remote communication towards M2M gateway or smart energy meter.

4.4 M2M gateway

The M2M gateway should ensure mass data transportation from many distributed energy meters in the field to one or several concentrated data collection hubs using public networks. The functions of this gateway need to support all possible data items from all connected meters, home automation and energy management systems.

The main issues of this M2M gateway are:

- remote communication;
- gateway between private and public networks;
- open for applicable data protocol, architecture and physical layers;
- remote reprogramming;
- security access;
- possible alliance with electricity meter.

Metering systems are the central data backbone of any smart metering infrastructure. As these systems may be connected to public networks and may operate in security related utility environments, a proper support of state-of-the-art security obligations and guidelines is mandatory. To enable open access to metering systems of several suppliers and technology vendors, head end systems need to support a common communication and data exchange standard. Central communication systems may be the communication gateway to public smart meter data portals and need to support open interfaces to such portals.

The main issues of this metering system are:

- data collector for M2M gateways and direct communications meters;
- data warehouse for billing systems;
- data and system access security;
- installation management;
- remote control of smart meters.

5 General Recommendations on PLT Communication

5.1 Frequency Bands

PLT for Smart Meters and Home Automation should operate in following Frequency Bands:

- CENELEC A, B and C frequency bands for Europe as specified in [i.2]; or
- Broadband PLT band 2 MHz to 30 MHz.

5.2 Coexistence with existing technologies

PLT for Smart Meters and Home Automation should coexist with:

- PLT technologies operating on powerlines in customer premises:
  - Including:
    - Broadband PLT systems operating above 1,6 MHz (e.g. IEEE 1901™ [i.9]).
    - IPTV services provide by Broadband PLT.
- Radio services as Long, Medium and Short Waves Broadcast as well as DRM (Digital Radio Mondiale) operating in customer premises and outside by meeting requirements specified in TS 102 578 [i.11].
- Broadband Access Technologies on telephone lines (e.g. VDSL2: Recommendation ITU-T G.993.2 [i.5]) operating in customer premises.

The coexistence should take in account any harmonics of PLC signals on the mains.

5.3 Power Consumption

PLT for Smart Meters and Home Automation may implement:

- Management of wake-up and idle modes minimizing the power consumption.

5.4 Transmission Robustness

PLT for Smart Meters and Home Automation should implement:

- PHY layer selection ensuring robust operation.
- MAC layer selection for lower data rates.
- Robust mode (by repeating data, if needed) overcoming noisy channel conditions.

5.5 Security

PLT for Smart Meters and Home Automation should implement:

- DLL adaptation layer to support IPv4 or IPv6 packets.
- Fast cryptographic engine.

5.6 Adaptive Communication

PLT for Smart Meters and Home Automation should implement:

- Adaptive tone mapping to maximize bandwidth utilization.
- Channel estimation to optimize modulation between neighbouring nodes.

6 Recommendations on PHY layer for Smart Meters

The PHY layer for transmission on PLC channels should meet the following requirements [i.6] and [i.7]:

1) Robustness: the communication profile should be suited to severe environments.

2) Performance: it should take full advantage of the CENELEC A band (if used).

3) Simplicity: it should be simple to implement using FFT, operate and maintain.

4) Flexibility: it should be compatible with diverse applications and network topologies.

5) Security: it should offer a safe environment for the promotion of Value Added services.

6) Openness: it should be based on open standards in order to support multi-supplier solutions.

7 Recommendations on MAC layer for Smart Meters

The MAC layer requirements for Smart Meter applications should take in account the transmission of low data rates (when used) on IPv6 (Internet Protocol), which opens a wide range of potential applications and services. The resulting small data packets should be managed by an adaptation sub-layer as 6LoWPAN [i.12] and [i.13] insuring the IPv6 and MAC interoperability. Broadband PLT IPv4 may be used as well as IPv6 (6LoWPAN is not required).

8 Recommendations on Transport layer for Smart Meters

The proposed communication model natively integrates a network layer and an IP suite transport layer which opens the way to a vast range of Internet applications and ensures great flexibility in the system architecture. It provides the possibility of having either a decentralized architecture, where the concentrator acts as an application relay, with more or less autonomy.

Reliability of exchanges within the PLC network is brought by the upper layers.

9 Recommendations on Application layer for Smart Meters

The Applications stratum covers layers 5 to 7 in the OSI model. The model proposed for metering (see figure 1) is somewhat simplified and comprises two broad classes of Applications: the Metering Application proper and the Applications ensuring the Management of the meter in the broad sense. It will be noted that all these applications rely natively on UDP, but there is nothing to prevent the future introduction of Applications that use TCP.

9.1 Metering Application

Security at application level is ensured by the processes defined in [i.6] and [i.7]. Other schemes are currently being specified, they will integrate naturally into the profile.

Transport of the COSEM Application protocol by UDP requires the inter-positioning of a "Wrapper" in accordance with IEC 62056-47 [i.3]. Although the title of the standard makes explicit reference to IPv4, it is applied with a few minor modifications to IPv6 and allows one to take advantage of the compression proposed by 6LoWPAN. This is a very simple stateless protocol that enables the number of ports to be scaled down. The header it introduces should be able to be compressed for low data rate PLC.

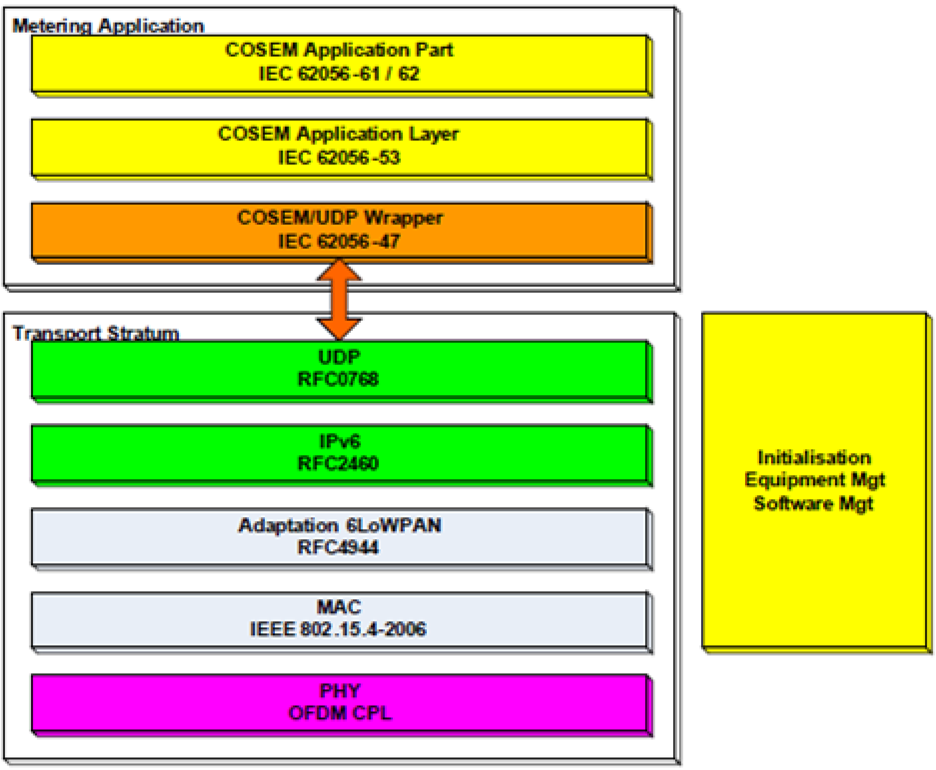

Figure 1: Metering Application in the OFDM PLC profile

10 Home Automation Recommendations

10.1 Scope of requirement

This clause focuses on Powerline communication requirements for Home Automation in the context of energy management and smart metering applications. The requirements generally apply to Physical layer, Media Access but are also applicable to liaison with Network layer.

10.2 Overview

Home automation devices represent for example control points for managing load, measuring consumption (e.g. electrical) or displaying information. Multiple nodes are then likely to be setup in every home. As a consequence, the global Home Automation nodes market surpasses largely the smart meter market. It is then fundamental that any standard describing Powerline Home Automation complies with the minimum requirements end users are asking for Consumer Electronics (CE) systems.

10.3 General requirements

Key factors for PLT home automation are:

1) Openness and availability.
2) Range.
3) Energy consumption.
4) Data rate.
5) Robustness.

6) EMC regulatory compliance.

7) Coexistence with other PLT technologies.

8) Security.

9) Latency.

10.3.1 Openness and availability

Open standards, compared to proprietary developments, are accelerating factors for the dissemination and the success of any mass-market technology. Standard openness encourages interoperability, stimulates multi-sourcing and low cost policies. The use of available standards, when adaptation to in-home PLT automation is possible, is a tremendous factor of stability and interoperability between existing mature technologies and new emerging ones.

- ETSI PLT command & Control standard should use existing, available and internationally recognized PHY, MAC and DLL technologies. Examples are: OFDM, IEEE 802.15.4™ [i.4], 6lowPan [i.12] and [i.13], IEEE 1901™ [i.9], HomePlug Green PHY [i.10], ISO/IEC 14908-3 [i.14], Recommendation ITU-T G.9901 [i.15] and Recommendation ITU-T G.9903 [i.6], etc.

10.3.2 Range

Range (or coverage) is one of the most important requirement in PLT. It is a very challenging one because of the extreme harshness of the medium. Multi Dwelling Units (MDU), where multi-phases networks can exceed a inter-node-distance of 100 m, are probably the worst-case situation in term of range performance.

- Any standard should be able to cover all outlets of the home.

10.3.3 Power consumption

Power consumption is a very sensitive parameter for command & control applications. This is specially the case for battery powered systems but is also true for PLT nodes. The main reason being that high power consumption supposes a large power supply unit leading to higher cost, higher thermal emission, shorter MTBF and bigger cases. Saving energy controlling lighting, especially with Compact Fluorescent Lights (CFL), can be very challenging with a high consumption PLT system.

- Standard should enable products to comply with European Directive 2005/32/EC [i.16] on energy consumption in Standby mode.

- Standard should enable products with low power consumption in relation to the savings users may request for energy efficiency products.

10.3.4 Data rate

Data rate is not a critical requirement per se for Home Automation applications. A data rate of 10 kb/s is, in most cases, enough to cover in-home applications like lighting or switching. However, factors like routing protocols, security, access to media mechanisms in a home with dozen of nodes will probably increase communication stream and payload.

- In case of very noisy channels, the standard should support variable data rate to keep reliable links.

10.3.5 Robustness

Home environment can be very challenging for PLT nodes.

Harsh channels in homes are due to various physical reasons:

- Low impedance appliances (from 1 Ω to 10's Ω, pure capacitive loads, etc.).

- Disturbance from common electric devices (chargers, dimmers, switching power supplies, etc.).

- Absorption from breakers and RCCB/GFCI.

- Electrical topology (multiphase wiring, neutral/ground connections, etc.).

In order to offer a good end-user experience:

- Standard should provide close to 100 % connectivity in home.
- Standard may use routing or/and data rate adaptation in order to keep connectivity in harsh environments.
- Standard should support multiphase topologies including with phase couplers.

10.3.6 EMC Regulatory compliance

- Standard should comply with European EMC regulations in force in the frequency band in use.

10.3.7 Coexistence

- Standard should implement existing coexistence standards when using frequency band where other PLT systems are transmitting.

  Coexistence standards already in use by legacy PLT systems are:

  - IEEE 1901.2™ [i.8] Section 10 Coexistence specification.
  - Recommendation ITU-T G.9901 [i.15].
  - Recommendation ITU-T G.9903 [i.6].
  - EN 50065-1 [i.1] C band: (channel busy signalling at 132,5 kHz).
  - ISP mechanism in the 2 MHz to 30 MHz band (as described in IEEE 1901™ [i.8] or Recommendation ITU-T G.9972 [i.2]).

- It is desirable to implement interoperability between Metering, Home Automation ETSI PLT standards and home networking (IPv4/IPv6). A bridge or gateway may be used between the two as necessary with clearly defined mappings.

10.3.8 Security

- Standard should provide services to support encryption and secure data services. However a compromise should be found between security and cost of implementation. Furthermore, plug and play installation may conflict with strong security requirements.
- The security suite should be open and available.

10.3.9 Latency

- Standard should support low latency communication in conformance with end-user usual expectation in Home Automation. Usually a latency of 200 ms is considered as a maximum for Home Automation applications.

History

Document history		
V1.1.1	January 2014	Publication