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Guideline for the Implementation of Coexistence for Broadband Power Line Communication Standards

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1. Overview

Power Line Communication (PLC) systems provide a bidirectional communication platform capable of delivering data for a variety of Smart Grid applications such as home energy management and intelligent meter reading and control. One benefit of applying power line communication on the power grid is that it provides an infrastructure that is much more comprehensive and widespread than other wired/wireless alternatives. The use of PLC in the home network enables home appliances and home energy management systems to communicate with no additional wiring and minimal configuration by the home owners.

The effective use of PLCs is impeded by the existence of multiple and non-interoperable technologies in use or under development in various standards developing organizations (SDOs). There are several SDO-based Broadband PLC (BB-PLC) technologies and more BB-PLC industry alliance-backed or proprietary solutions. Not only do these technologies not interoperate, but simultaneous operation of these technologies using the same frequency bands in proximity may cause harmful mutual interference which may lead to severe performance degradation or even malfunctions in both Smart Grid and/or home networking applications. The Smart Grid Interoperability Panel (SGIP) established the Priority Action Plan 15 (PAP 15) to address these issues, with special focuses on harmonization of PLC standards and their coexistence specifications.

At the time PAP15 was established in 2009, there were two BB-PLC standards close to being approved by SDOs - IEEE 1901 by the Institute of Electrical and Electronics Engineers (IEEE) Project P1901 and ITU G.hn by the International Telecommunication Union Telecommunication Sector (ITU-T).[1] Coexistence between these standards became an urgent matter; therefore a PAP-15 "Coexistence" subgroup was formed. This guideline describes the results of this effort, and how the coexistence standards for the BB-PLC should be used.

2. Why Is Coexistence Important

Power line cables are a shared medium. Thus, they cannot provide links dedicated exclusively to a particular subscriber as other cables such as twist pairs. More specifically, power line cables connect a low-voltage transformer to a set of individual homes or set of multiple dwelling units without isolation of each unit. Since power line cables are shared among a set of users (aka “neighbors”), the signals that are generated within the premises can interfere with signals generated outside the premises, e.g., at the meter, in the low voltage distribution part of the grid, etc. Similarly, signals generated in one apartment or house may interfere with the signals generated in an adjacent house or apartment. Since it is difficult to locally contain

[1] There was another BB PLC standard approved by IEC in the same time frame, ISO/IEC 12139-1 [10]. The coexistence mechanism discussed in this document does not address coexistence with this standard. Coexistence between these three standards is an open issue.

the signals generated by a user, the more users in geographical proximity that use PLC technologies operating in the same frequency band, the more interference is generated on the power line both indoors and outdoors. As the interference increases, every user will experience a decrease in data rate or an interruption of service as more packet collisions occur.

This occurrence of network overlap is not dissimilar from what happens in other more conventional shared media, e.g., coax and wireless. However, coax and wireless devices can count on the availability of a much larger bandwidth than in the power line case and can therefore mitigate the effects of interference by using different communication channels separated in frequency. For this reason, it is necessary to devise coexistence mechanisms to limit the harmful interference caused by non-interoperable neighboring devices.

3. Broadband PLC Standards

PLC Technology could be classified into two general categories: Narrowband (NB) and Broadband (BB). NB-PLC operates in frequency bands below 500 kHz and has bandwidth in tens to hundreds of kilobits per second (Kbps); BB-PLC operates in the frequency bands over 1.8 MHz and can have a bandwidth ranging from several megabits per second (Mbps) to a few hundred Mbps. For a more detailed discussion of the PLC technology and its use in the Smart Grid, please see [1].

Among the existing BB-PLC protocols, PAP15 focused on two SDO-based PLC technologies: IEEE 1901-2010 [2] and ITU-T Recommendations G.9960/G.9961 (G.hn) [3]. These SDO-based technologies can coexist using the Inter-System Protocol (ISP), which is specified in IEEE 1901 and ITU-T Recommendation G.9972 [7]; for more details on coexistence, see [1] and [8].

IEEE 1901 [2]: The IEEE P1901 project was established in 2005 with the goal of developing a standard for high-speed communication (>100 Mbps) devices using frequencies below 100 MHz and addressing both HAN and access applications. The 1901 standard defines the Medium Access Control (MAC) and the Physical medium (PHY) specifications, and includes two different non-interoperable technologies: a fast Fourier transform orthogonal frequency division multiplexing (FFT-OFDM) PHY/MAC and a Wavelet-OFDM-based PHY/MAC. The 1901 standard also contains the mandatory coexistence mechanism ISP in the same document that allows the two IEEE 1901 PHYs/MACs to share channel resources fairly.

ITU-T G.9960, G.9961, G.9963, and G.9964 [3]-[6]: The ITU-T started the G.hn project in 2006 with a goal of developing a worldwide recommendation for a unified home networking transceiver capable of operating over all types of in-home wiring: phone lines, power lines, coax, Cat 5 cables, and plastic optical fibers at a bit rates up to 1 Gbps. G.hn does not mandate the implementation of BB-PLC coexistence, and G.hn devices that wish to support coexistence must also implement ITU-T recommendation G.9972 [7].

4. PAP 15 and coexistence standardization

When PAP 15 started, the primary goal was to harmonize the various technologies, or select one and move forward. This proved impossible to accomplish because there was no consensus on adopting a single BB-PLC technology. Therefore, the group began working to make sure there was a single BB-PLC coexistence mechanism available so that BB-PLC devices would

not interfere with each other. This prompted the creation of a PAP 15 Coexistence Subgroup in early 2010.

By 2010, two SDOs were working on coexistence: IEEE and ITU-T. The IEEE P1901 Working Group established coexistence requirements and defined a mandatory coexistence mechanism called Inter-System Protocol (ISP) that allows coexistence between devices implementing either one of the two PHY/MACs defined in the IEEE 1901 Standard. The ISP coexistence mechanism defined in IEEE 1901 was also submitted to the ITU-T G.hn Working Group with the goal of extending IEEE 1901 coexistence to include ITU-T G.hn devices. Coexistence work was subsequently spun out of the G.hn project, and another ITU-T project called G.cx was then created with the purpose of creating a BB-PLC coexistence recommendation based on ISP. The output of the G.cx project would then become the BB-PLC coexistence Recommendation ITU-T G.9972, which received final approval in June 2010 [7]. Although the very same ISP coexistence mechanism was the basis for both the IEEE and ITU-T specifications, the two different comment resolution phases followed by the two Working Groups caused a divergence of the ISP specifications in the IEEE and ITU-T drafts. This divergence resulted in an incompatibility between the ISP as specified in IEEE 1901 and as specified in ITU-T G.9972.

As the two SDOs were close to final ratification, PAP 15 took immediate action for the realignment of the two specifications. Under the oversight of the PAP 15 coexistence subgroup, a BB-PLC coexistence Focus Group was created in February 2010. The Focus Group was composed of members of both the IEEE and ITU-T Working Groups, and its goal was to work towards identifying the sources of incompatibility and to discuss remedial actions.

All causes of incompatibility in the IEEE and ITU specifications of ISP have been eliminated as of June 2010 and before final approval of the IEEE 1901 standard and the ITU-T Recommendation G.9972. One notable difference between the two coexistence specifications is that IEEE 1901 also supports coexistence with Low Rate Wideband Services (LRWBS) whereas ITU-T G.9972 does not. However, this difference does not affect the compatibility of the two BB-PLC coexistence recommendations with respect to the coexistence between IEEE 1901-compliant devices and ITU-T G.996x-compliant devices that also implement ITU-T G.9972, and furthermore, any IEEE 1901-compliant device is also G.9972-compliant.

5. Recommendations to SGIP from PAP15

Under the coordination of the PAP15 Coexistence Subgroup, the harmonized BB-PLC coexistence specifications were approved by ITU-T and IEEE as:

A. Recommendation ITU-T G.9972 (2010), Coexistence mechanism for wireline home networking transceivers, Jun. 2010 [7].

B. The ISP part of the IEEE Standard 1901-2010, IEEE Standard for Broadband Over Power Line Networks: Medium Access Control and Physical Layer Specifications, Sept. 2010 [2], which includes the entire Clause 16, and the ISP-related parts of Clause 3 (terminology), Clause 4 (ISP architecture), and Clause 15 (mapping of ISP and IEEE 1901 coexistence procedures).

The above two documents were approved by PAP 15 at its meeting in Chicago on December 2, 2010.

In addition, PAP 15 members also produced a document with a recommendation for the SGIP on implementation of these coexistence standards. The full text of the document can be found in [9], whereas the final recommendation in Sect. 4 of [9] is reported below:

1) Include the ISP-based BB-PLC coexistence standard ITU-T G.9972 in the list of standards recommended for the Smart Grid and add a remark that ITU-T G.9972 is compatible with the ISP defined in the IEEE 1901 Standard.
2) Add a remark to the already listed IEEE 1901 Standard that its specifications include as mandatory the ISP coexistence mechanism, which is compatible with the one defined in Recommendation ITU-T G.9972.
3) Mandate that all BB-PLC technologies operating over power lines (either the ones currently listed in the list of recommended standards or the ones that may be added in the future) include in their implementation either Recommendation ITU-T G.9972 or ISP as specified in IEEE 1901, as appropriate.
4) In order to be compliant with this recommendation, IEEE 1901-compliant devices must implement and activate ISP (i.e., be always on), ITU-T G.9960/G.9961-compliant devices must be compliant with and activate ITU-T G.9972 (i.e., be always on), and any other BB-PLC technology must be compliant with and activate coexistence (i.e., be always on) as specified in ITU-T G.9972 or as in the ISP of IEEE 1901, as appropriate.

While the two coexistence standards A) and B) above have undergone a review by the SGIP Working Groups, concerns were expressed on how to maintain compatibility in future revisions of these standards. To address these concerns, the SGIP requests that IEEE and ITU-T submit future versions of the ITU-T Rec. G.9972 [7] and the ISP-related portion of the IEEE 1901 standard [2] to NIST and SGIP for update of the SGIP Catalogue of Standards.

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