Lower Layer Design of Narrowband PLC Node for AMR and AMM Applications and Network Layer Protocol Verification

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Abstract. *This paper describes design of a network node, which uses narrowband powerline communication for data exchange in AMR and AMM networks. Also an implementation of first two ISO/OSI layers is described in this paper. Data reception synchronization and some indicators for upper layer functions as the capabilities of physical layer are detailed. A passage about data link layer is focused on the frame structure and implementation of FEC and ARQ methods for reliable data transfers.*

Keywords: Narrowband Powerline Communication, Media Layer Protocols, AMM and AMR Systems

1. Introduction

Automatic Meter Reading (AMR) and Advanced Metering Management (AMM) are relatively new ways for data collection from electricity, gas and other meters. These systems provide accurate view on consumer demand thus allowing media providers to control their networks more easily and effectively. AMM systems can also support direct control of media delivery points. This can be helpful, when company wants to disconnect media flow to delivery point or just to reduce it. Energy and media providers often tend to narrowband powerline communication (PLC) at the last mile of these data collecting systems. PLC is preferred for its simplicity and cheapness compared to extra data buses or wireless solutions. Main advantages in comparison with a broadband PLC communication are generally lower signal attenuation at low frequencies and the regulations allowing only energy providers to transmit in 9 – 95 kHz bandwidth in power lines. Fully working network of PLC nodes with effective lower (media) layer protocols would be capable to collect data from the covered area easily and with lover costs then other mentioned systems.

2. Powerline Communication and Design of a PLC Node

Channel Characterisation

Power lines are primarily designed for electrical energy delivery with no regards for data transmissions. Data transfers are obtained by the use of some digital modulation technique with carrier frequency in range of tens of kHz for narrowband PLC and MHz to tens of MHz for broadband PLC. Power line parameters are frequency dependent on connected loads. It means that the impedance of connected loads can rapidly change the signal attenuation at measured distance. Generally the attenuation is higher with increasing frequency and therefore the narrowband PLC can work at longer distances than the broadband PLC. Another effect, which makes problems in PLC, is the noise produced by connected loads. It can be a background continuous noise from universal motors, short strong impulses from switching electrical circuits, synchronous and asynchronous noise from switching with mains frequency or from switched power supplies. All described characteristics of the power lines are not stable. They are time varying, therefore the power lines are very hostile and hardly predictable for the data transfers. Powerline channel between two communicating nodes is often asymmetric due to the different position of noise sources. This has to be considered within the development of PLC node and protocols for communication.

Physical Layer

The first version of hardware design of my PLC node consists of two boards (Fig. 1). The first is a ST7540 narrowband PLC modem based board with coupling circuits and communication interface. The second board is based on 40 MHz ARM7 core microcontroller equipped with serial interfaces and interface for PLC board communication. Communication protocol stack implementation is written in C language with possibility to insert upper layers in future.

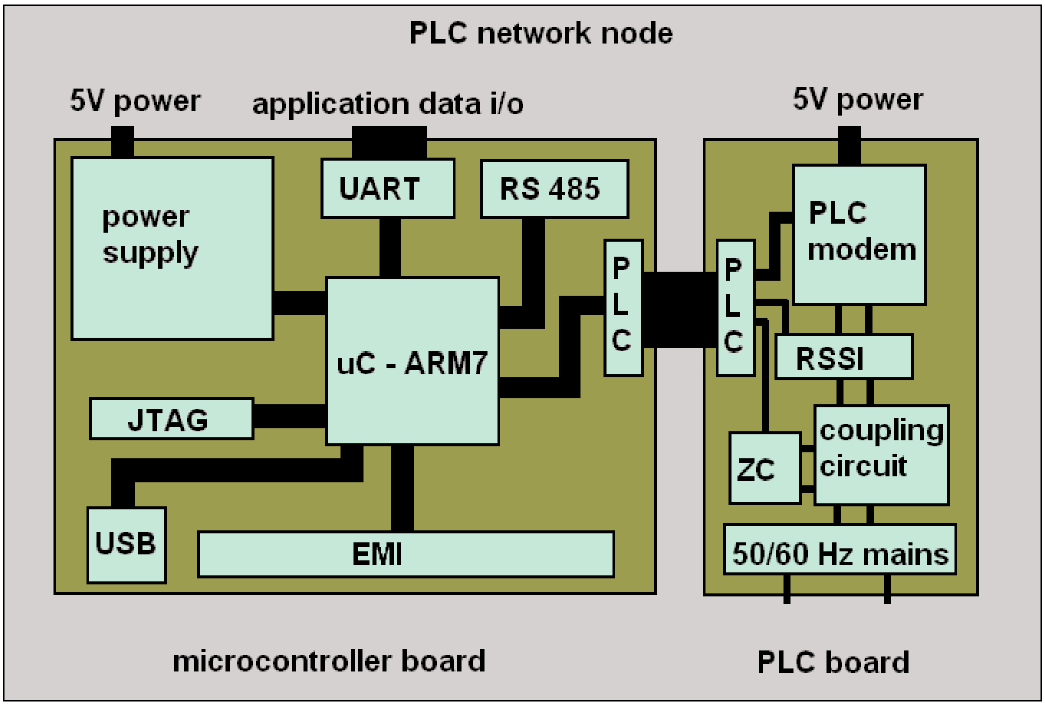

Fig. 1. Block scheme of PLC network node

The PLC modem uses binary FSK modulation for data transfers. It supports 4 bit rates, carrier and preamble detection, automatic output level control, input digital filtering, input sensitivity setting and 6 different carrier frequencies in A and C bands of the CENELEC EN 50065. The coupling circuit is a band-pass filter designed for 72,05 kHz centre frequency. Bit rate is set to 4800 b/s and the host communication utilizes a synchronous SPI interface.

Physical layer software protocol stack implementation contains buffers and functions for physical layer data frame transmission and reception. The structure of the physical layer frame is shown in Fig. 2.

Fig. 2. Structure of a physical layer frame

As in other similar communication methods the data are correctly stored after reception of the synchronization sequence. It is indicated by proper synchronization sequence recognition, which follows the preamble sequence of zeros and ones used for the modem bit synchronization. Because of the strong disturbances in power lines it is necessary to ensure the proper reception even with some degree of errors in synchronization sequence (3 errors in first 16 bits and 8 in following 32 bits are accepted in my case). This synchronization sequence is relatively long, as it was designed to capture frames more correctly for an accurate BER measurement compared with simple 16-bit synchronization. Future development will probably lead to shorten the synchronization sequence. The physical layer provides data link layer information (for MAC protocol), whether node is busy or communication channel is occupied.

Another important capability of physical layer is a Received Signal Strength Indicator – RSSI. In-band signal strength can be provided to data link layer to support the MAC protocol and the received signal strength during the frame reception can be provided to the data link layer or to upper layers. This indicator is especially relevant for network layer routing protocol.

Data Link Layer

The data link layer takes care of data exchange between two nodes, which are close to each other and able to communicate directly. Addressing of nodes was designed with regards to the first proposed version of the network layer protocol. A structure of the typical data link layer frame for data transfer is at Fig. 3.

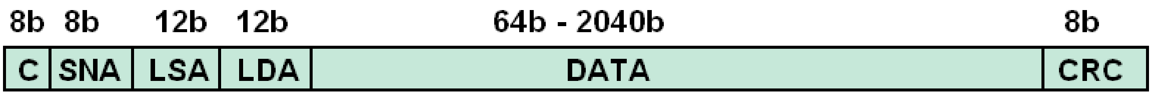

Fig. 3. Structure of a data link layer frame

The first byte defines the frame type. Next byte represents a subnet address, which allows coexistence of more than one network of these nodes under the control of different data concentrators. Following three bytes are link layer source and destination addresses. Next follow the upper layer data and 8-bit CRC fields.

The data link layer supports frame acknowledging and ARQ method for data exchange. The acknowledge frame has the same structure as a normal data link frame and in the data block it carries information about the quality of received frame reception. The protocol allows up to four retransmissions. This method improves data transfer reliability when long burst errors are present in powerline communication channel.

Power lines are very hostile and noisy environment for PLC, so it was necessary to implement a forward error correction (FEC). For the future optimization of the transmission power efficiency 3 levels of forward error correction methods were implemented. The data link layer then supports 4 types of data processing based on the applied BCH codes and interleaving. Approximate relation of measured BER and signal to noise quotient for all implemented FEC methods is shown in Fig. 4. The best performance in reliable area for data transfers (under 0,5 % error rate) has concatenation of BCH codes combined with interleaving for better burst error correction. Disadvantage of this relatively strong FEC is 3,4 code rate, but it’s the only simple way to transfer data without repeaters, when the S/N ratio is decreasing closer to zero.

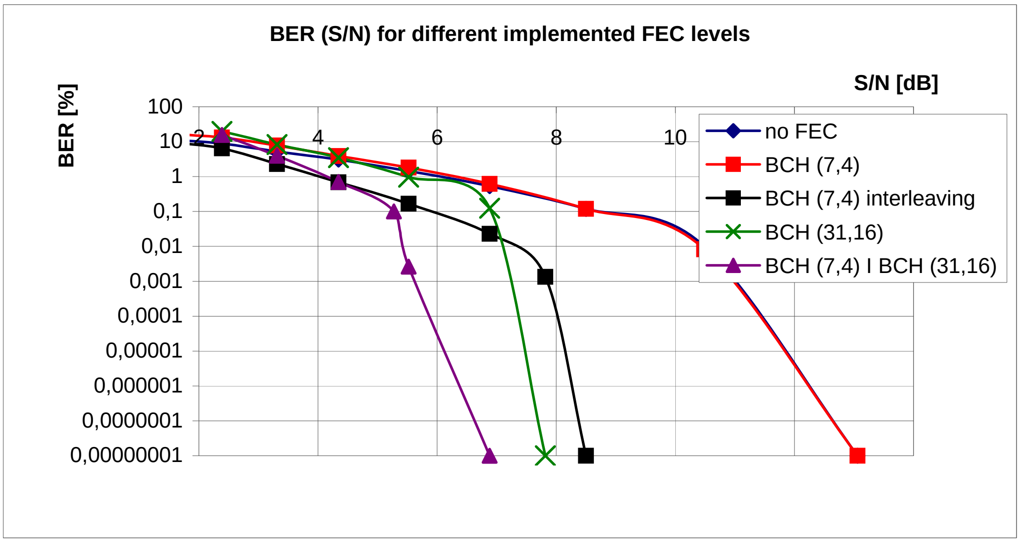

Fig. 4. Comparison of BER in relation with S/N of implemented error correcting coding methods

3. Conclusions

This robust lower layer protocols implementation ensures reliable data transfer over the low voltage power lines. All described methods and procedures are essential for communication in such a noisy and unpredictable channel. The BER measurement shows that strongest implemented level of FEC improves reliability of data transfers, when S/N ratio is getting lower due to the distance between nodes or higher level of noise in power lines. The coding gain between data transfers with no FEC and strong FEC with concatenation of two BCH codes and interleaving is 5dB. This is of course further improved by the use of ARQ method. The described protocols will be improved and optimized for the transmission power efficiency in future. Next important level dealing with narrowband PLC for AMM and AMR is network layer protocol. Network protocol is important, because it makes it possible to send data at longer distances and in more noisy networks, when physical and data link layers are unable to reach all nodes in network. The physical and link layer implementation will further be used for verification of the adaptive network layer protocol focused on minimized power consumption of the overall network communication.

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