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Study on Efficient Impulsive Noise Mitigation for Power Line Communication

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Abstract

In this paper, we propose the efficient impulsive noise mitigation scheme for power line communication (PLC) systems in smart grid applications. The proposed scheme estimates the channel impulsive noise information of receiver by applying machine learning. Then, the estimated impulsive noise is updated in data base. In the modulator, the impulsive noise which reduces the PLC performance is effectively mitigated through proposed technique. As an impulsive noise model, Middleton Class A interference model was employed. The performance is evaluated in terms of bit error rate (BER). From the simulation results, it is confirmed that the proposed scheme has better BER performance compared to the conventional model. As a result, the proposed noise mitigation improves the signal quality of PLC systems by effectively removing the channel noise. The results of the paper can be applied to PLC systems for smart grid.

Keywords: *Power Line Communication, Smart Grid System, Noise Mitigation, Impulsive Noise, Machine Learning*

1. Introduction

The goal of the smart grid is to use advanced information technologies to increase power grid efficiency, reliability, and flexibility and reduce the rate at which additional electric utility infrastructure needs to be built [1]. In addition, explosive increase of demands for high quality of multimedia and convenient access has led to a variety research of communication technologies. To support the smart grid and meet the customer's needs, communication technologies should be supported fast data rate, reliable reception and access in anywhere. Power line communications (PLC) have become an attractive communication solution for smart grid than other applications due to their advantages of low installation costs over other communication technologies [2, 3]. Besides this, communication service can be available everywhere outlets exist. As shown in Fig. 1, PLC technology is mainly employed for access network and in-home communications networks. Since power line, however, have been made for electricity distribution purpose, its channel characteristic is very hostile for data transmission. There are lots of devices with variety impedance in PLC network, so this cause multipath environment. Also, impulsive noise is generated by random joint of each device, which sometimes exceeds power spectral density (PSD) of background noise by 50 dB [4]. It needs to mitigate impulsive noise because these are critical to the system performance.

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In this paper, machine learning based efficient noise mitigation scheme as a method to overcome above issues is proposed. This paper is organized as follows. In Section 2, we describe the PLC system and the proposed PLC system model is presented in Section 3. Simulation results are shown in Section 4. Finally, Section 5 concludes the paper.

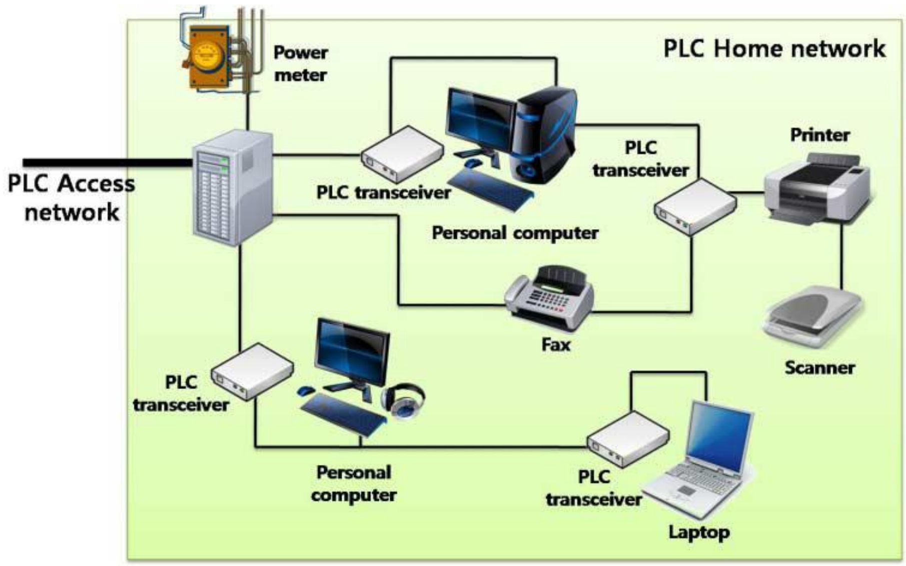

Figure 1. PLC home network

2. Power Line Communication

PLC is one of the promising communication technologies. This technology literally transmits data on electric power from a small number of sources to a large number of sinks in the frequency range of 50~60Hz [5]. PLC technology begins to receive explosive attention in the smart grid and the home networking industry because of its several attractive advantages. The most useful advantage of them is a national-wide power line infrastructure. PLC is one of the promising communication technologies. This technology literally transmits data on electric power from a small number of sources to a large number of sinks in the frequency range of 50~60Hz [5].

PLC technology begins to receive explosive attention in the smart grid and the home networking industry because of its several attractive advantages. The most useful advantage of them is a national-wide power line infrastructure. It is very robust and can be utilized anywhere using electricity. This point approaches low installation cost since it uses existing line as communication. Power line is originally, however, designed for power delivery, not for data transmission. Therefore, there are many difficulties in data communication with power line. Varying impedance, considerable noise which includes white noise as well as impulse noise, and high levels of frequency dependent attenuation are the representative issues such as cable loss, multipath fading, and noise [6, 7].

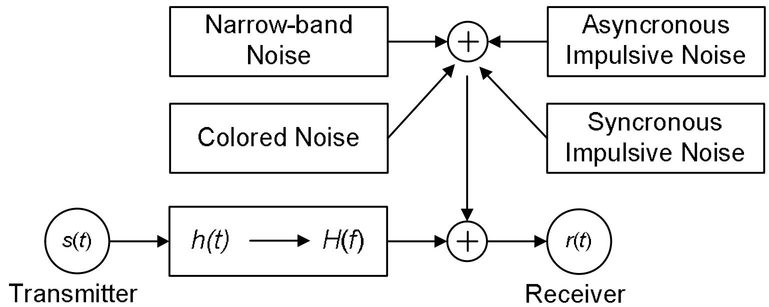

Figure 2. Multipath noise model

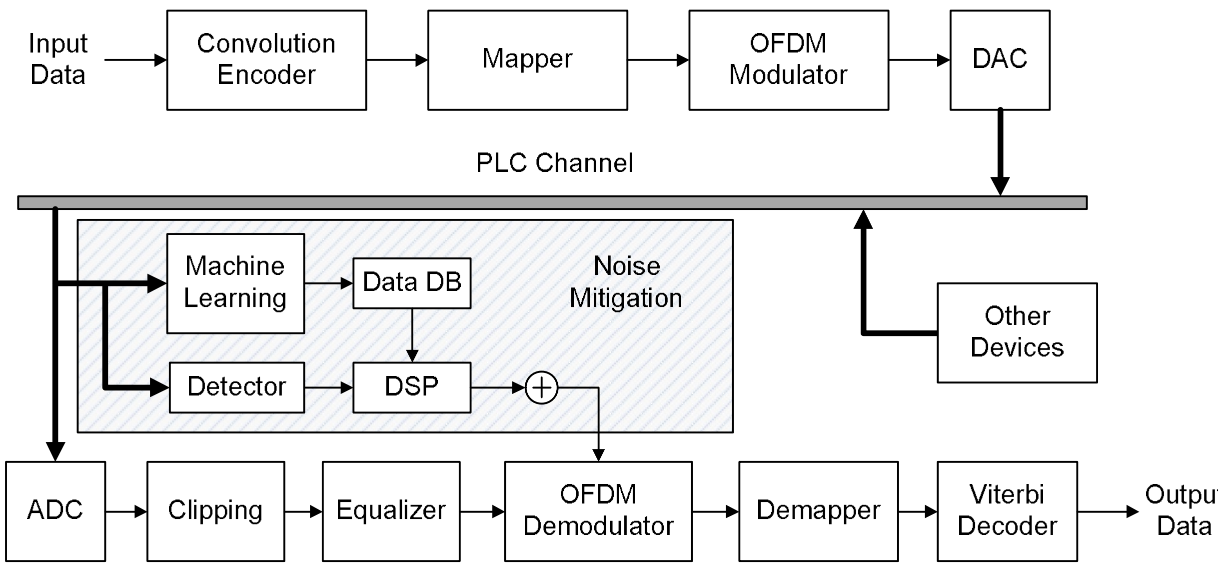

Figure 3. Block diagram of proposed PLC Systems

Fig. 2 illustrates a noise block diagram in PLC channel. The noises can be typified into five categories: colored background noise, narrow-band noise, periodic impulsive noise synchronous or asynchronous to the main frequency (50~60 Hz), and asynchronous aperiodic impulsive noise [8]. Some noise among them rarely has properties similar to the easily analyzed white Gaussian noise of the receiver. The background, narrow-band, and periodic asynchronous noise may be summarized as background noise since their properties are typically stationary over periods of seconds and minutes or sometimes even for hours. However, asynchronous impulsive noise and periodic synchronous impulsive noise are varying rapidly for microseconds to milliseconds. Therefore, it is necessary to set up impulsive noise model. In this paper, the Middleton's Class A noise model is considered to establish impulsive noise.

3. System Model

Figure 3 show the block diagram of proposed PLC system. Binary data stream is modulated by channel coding at the convolution encoder. The channel coding compensates for the effect of channel fading. Then, the phase shift keying (PSK) modulated signal is changed serial signal to a number of parallel frames. Each frame is loaded subcarriers and summed up through inverse fast Fourier transform (IFFT). This signal is converted to analog at the digital-to-analog converter (DAC) and then transmitted via power lines. The received signal experienced a variety of noises changed to digital signal again at the analog-to-digital converter (ADC). The noises of electrical device from home network have a multipath scenario with frequency selective fading, and it produces unpredictable noises with electrical resonance of each device. At the receiver, the channel noise is estimated by feedback process, and the noise model is optimized through machine learning. In this paper, the machine learning based on multi-layer perceptron is applied, and the estimated error is minimized using the Adam optimization algorithm [9]. Then, the estimated impulsive noise is updated in data base. In the modulator, the received signal is reconstructed by eliminating the estimated impulsive noise in the database. These repetitive tasks effectively eliminate impulse noise. Finally, the received signal is recovered as the original data stream via FFT and demodulator. PLC has hostile transmission channel due to the variance of impedance caused by a variety of appliances that could be connected to the power outlets. Additional paths must also be considered, because the signal reflection occurs at the impedance mismatching part. Therefore, the multi-path channel has a frequency selective fading [6]. In this paper, the multipath channel model proposed in [7] is applied.

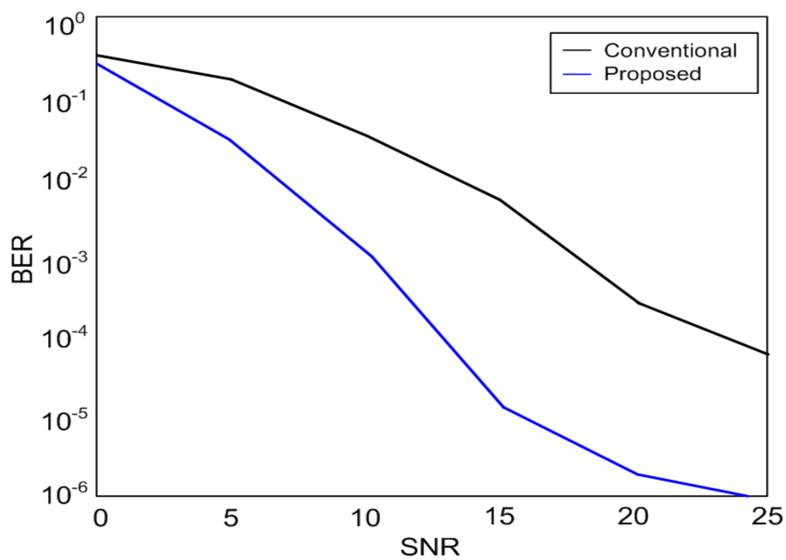

Figure 4. Performance of the coded-PLC system employing noise mitigation

4. Simulation Results

In this section, the performance of the proposed PLC system with impulsive noise mitigation scheme is simulated. In machine learning model, it is hard to find the optimal number of neurons. The best efficient model can be found through having been applied on experience in database. The 98% accuracy model is applied in this paper, and the accuracy can be improved through repeated learning for data set. Fig. 4 shows the bite error rate (BER) performance for PLC system with proposed scheme. The noise mitigation scheme shows better performance than the conventional scheme. When signal-to-noise ratio (SNR) increases, the noise mitigation effect is reduced because the accuracy of machine learning model is not perfect. Nevertheless, through channel estimation block based on machine learning, the impulsive noise from electrical devices can be effectively eliminated.

5. Conclusion

In this paper, the performance of PLC systems using the noise enhancement technique is analyzed and simulated. The proposed scheme estimates the channel impulsive noise based on machine learning process. It effectively reduces the impulsive noise which affects the PLC performance. From the simulation results, it is confirmed that the BER performance of PLC systems with proposed scheme was improved in comparison with the conventional scheme. The results of this paper can be applied to reduce impulse noise in the PLC system for smart grid applications.

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