Simulation of wireless sensor node transmission over a multiple access channel

Katleho Kanyane, Babu S. Paul, Suvendi Rimer, and Khmaies Ouahada

Department of Electrical Engineering,
University of Johannesburg,
Johannesburg, South Africa
kkanyane@gmail.com, suvendic@uj.ac.za

Abstract. Smart Grids are emerging as a sustainable technology that can greatly improve the quality, cost and efficiency of electrical power distribution. Wireless communication technology, in particular wireless sensor networks, are being considered as a viable solution to Smart Grid communication requirements. Homes have multiple electrical appliances that may communicate concurrently. In addition, electrical appliances induce white noise that can interfere with the wireless signal. In this paper an indoor wireless sensor multiple access communication environment is simulated based on the IEEE 802.15.4 wireless communication standard. An indoor wireless propagation model is implemented and the effects of signal interference on the wireless signal are examined.

Key words: Smart Grid; Wireless Sensor networks; IEEE 802.15.4 ;Wireless channel; Wireless interference; Indoor path loss model

1 Introduction

An electric grid having smart capability allows the power providers, distributors, and consumers to maintain a near real-time awareness of one anothers operating requirements and capabilities. Through this awareness, the Smart Grid is able to produce, distribute, and consume power in the most efficient and intelligent way. Two-way digital communication is an important enabling technology to Smart Grids [1].

Currently, most residential energy usage is from appliances used for lighting, cooking, indoor temperature control (such as heating or cooling systems), washing, and drying and entertainment purposes. Wireless sensor nodes connect equipment such as television, washing machines, etc., to a home are network (HAN) gateway (or coordinator), which in turn communicates with a larger smart grid network infrastructure. Wireless sensor nodes in a HAN would be used to collect user data and relay it to a local coordinator node [2]. The gateway node would gather the data from different wireless nodes and forward it to the power utility company for processing. In this environment several wireless sensors and gateways would be deployed.

The wireless signal between the sensor node and the gateway will experience fading and interference as well as attenuation due to transmission through multiple inner walls. In addition, wireless nodes from closely spaced homes (such as apartment buildings), may be communicating simultaneously to their respective gateway node. A suitable channel access method must be selected to ensure reliable real-time communication between then nodes.

In this paper a Matlab simulation is used to investigate the propagation effects of an unmanaged multiple access channel to further understand the constraints imposed on the selection of the multiple access technique to use in wireless sensor networks deployed in Smart Grids.

Section II explains the design of the Matlab simulation of the wireless sensor network. The results and analysis of the results are documented in section III. The paper ends with a Conclusion in section IV.

2 Algorithm Design

The scenario simulated consists of a group of nodes, where each node is located in a different room and 8m apart from its nearest neighbour. The simulation considers the case where all the nodes are transmitting at the same time. A situation where each node in the network transmits to a single node may occur where each node transmits directly to a single sink node during the contention period in TDMA. The communication between two nodes in this environment is simulated and analysed. Only the physical layer baseband communication is considered. It is assumed that each node is transmitting at the same frequency.The simulation is developed for 2 x 6 residential apartment with each node located at the centre of each room.

The simulation is based on the IEEE 802.15.4 specification in the Industrial, Medical and Scientific (ISM) 2.4 GHz frequency band. The minimum transmit power is set to 33 dB according to the Texas Instruments data sheet for a 2.4 GHz IEEE 802.15.4 ZigBee RF transceiver [3]. The channel access method used is TDMA.

The simulation begins by generating a binary signal with bit values of -1 and 1. The gain of the transmitter is then applied to the signal and transmitted over the channel.

The signal power at the receiver P in dB, is calculated by taking the transmitter power P over the path loss L The power loss over the transmitted distance is computed using the ITU Indoor Path Loss model in the 2.4 GHz frequency band shown in equation 1 [4].

$$L_{total} = 20\log_{10} f + N\log_{10} d + L_f(n) - 28 \; . \tag{1}$$

$$P_{r(dB)} = \frac{P_{t(dB)}}{L_{total}} \; . \tag{2}$$

The simulation first calculates the bit error rate of the received signal as a function of the signal to noise ratio at node 1 when node 2 is only transmitting with the path loss and noise being computed at the receiver. Then the signals from 6 adjacent nodes, at the same distance as the transmitter node are factored in by using equation 1 and increasing the power of the interfering signal by the same signal power as the single node interfering power.

3 Results and Discussion

1000 messages with 1000 bits were generated as the input message. Each message was compared with its corresponding received message and the bit error rate was computed. The bit error rate was calculated for signal to noise ratios from 1 to 30 decibels. Fig 1 and Fig 2 are the plots of the bit error rate (BER) versus the signal to noise ratio at the receiver for the signal at the receiver for the different interference powers.

In Fig. 1 and Fig. 2 the bit error rate improved as a function of the signal to noise ratio. Even at very low SINR, the effect of interfering signal is noticeable Fig (1), where the probability of error increases from 0.15 for no interference to 0.2 for 6 interfering signals at 0dB. A plot of the bit error rate versus the number

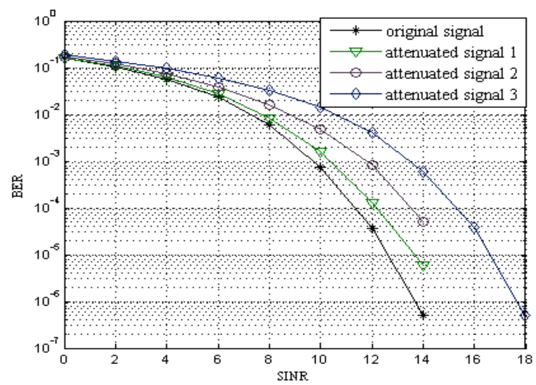

Fig. 1. Bit error rate versus SINR for increasing interfering signal strength

of interfering signals was generated from the experimental data to investigate the effect of increasing interference on the bit error rate. Fig. 3 shows the bit error rate deteriorates as more interfering signals are present. It can also be seen that the rate at which the BER deteriorates increases non-linearly with the number of interfering signals. Fig. 4 is the plot of the change in the SINR versus the number of interfering signals. This plot was generated by setting the BER to a fixed value and computing the SNR values for different interfering signals from the experimental data. From this plot it can be seen that increases to the signal to noise ratio yield less improvements to the BER.

There is only a maximum of 1.65dB difference for bit error rates of 10-4and 10-5 while for BER 10-2 and 10-3 the maximum difference is 2.95dB. The graph also shows that to maintain a constant BER, the SNR increase per interfering signal becomes higher as the number of interfering signals increases.

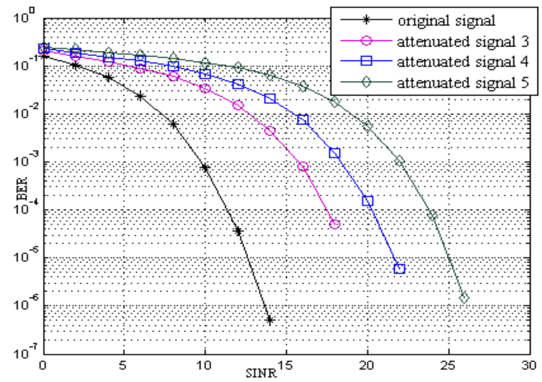

Fig. 2. BER vs SINR

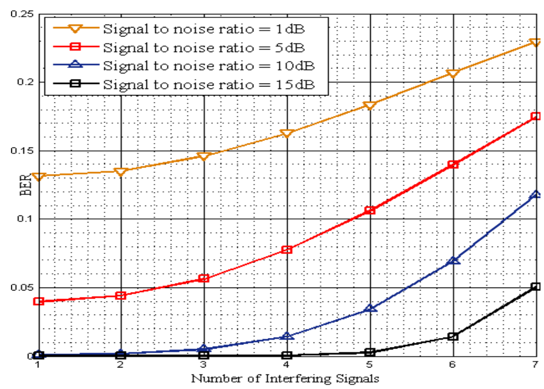

Fig. 3. Bit error rate versus number of interfering signals with plot for signal to noise ratios 1dB, 5dB, 10dB and 15dB

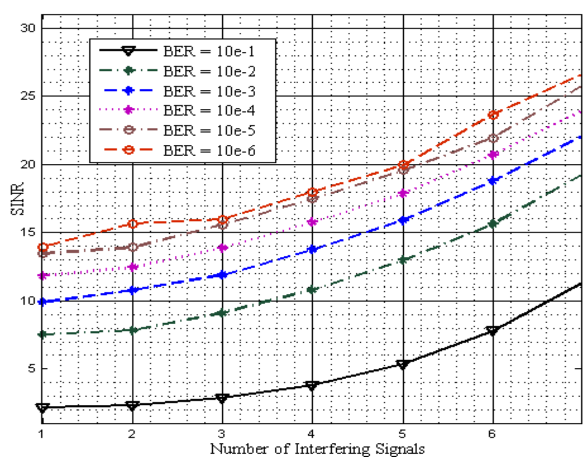

Fig. 4. Change in the SINR versus the number of interfering signals

4 Conclusion

This paper presents a Matlab simulation of a baseband IEEE 802.15.4 wireless communication between wireless nodes with interference from neighbouring nodes. The simulation considers the effects of indoor path loss through the use of the ITU indoor path loss model for indoor residential signal propagation. The effects of the interference from adjacent nodes are investigated with respect to the signal to noise ratio and the bit error rate at the receiver.

The analysis shows that the degradation to the BER is non-linear with respect to the interfering signal power. From the simulation it can be seen that to maintain a required BER, the increase in the signal to noise ratio was non-linear.

From the Matlab simulation it is shown that for a small 7 node wireless network, the effects of interference are large, further illustrating the requirement for an appropriate channel access method for real-time wireless communication.

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