Improved IEEE 802.15.4 Physical Layer using 16x16 Antenna Configurations

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Abstract - Zigbee standard is very famous for transmission on low power specially in the devices like wireless mouse and keyboards. Several research on Zigbee technology are being carried out for better and better performance in terms of error probability or end to end performance. The lower error rate performance indirectly save energy of IEEE 802.15.4 data transfer. In this research paper higher order spatial diversity using multiple input multiple output (MIMO) technology is utilized to enhance the performance of the Zigbee technology. In addition of proposed spatial diversity architecture O-QPSK is adopted which better perform with the standard than other modulation techniques. The proposed system is tested for transmitters and receiver considering 8, and 16 antenna pairs and found better results.

Keywords:IEEE 802.15.4, OQPSK, Spatial Diversity and Zigbee.

I. INTRODUCTION

An increasing trend for ubiquitous computing leads to the need of monitoring and controlling everything, in a pervasive fashion. The dawn of the next generation of Internet services (e.g. Google Maps [1], Sensor Maps [2]) and the evolution of mobile services along with the gigantic advancement of information and communication technologies (namely on memories, batteries, energy scavenging techniques and hardware designs), and necessity of large-scale communication infrastructures triggered the birth of the Wireless Sensor Network (WSN) paradigm.

In the upcoming years, wireless communications will be part Of everyday objects. The potential of wireless communications are unlimited as most entities will intercommunicate and interact. Wireless would be embedded in all objects, from small items such as clothes, the mobile phones, the gadgets, toys, and home appliances, food carts to cars, the bridges, roads, the farm lands, buildings, animals and people. That computing ubiquity will helps for improving the quality of life and will change people's habits. While this reality is still at its early days, technologies and uses are evolving at dramatic speeds. General consensus is that there is technological potential for these new applications; the big issue is to make this economically viable as information technology has nothing to lose but its cables. Integration of a wireless module is not just enabling a way to communicate but it is a mean to make objects smarter and granting those new abilities [3].

Many new problems and challenges must be overcome in Wireless Sensor Networks as their paradigm differs from traditional wireless networks. There is the need for low cost devices enabling large-scale applications (as there can be hundreds or thousands of nodes scattered in large areas) and energy requirements that impose low communication rates and ranges and low duty cycles. Several of the challenges in WSNs are energy efficiency, routing, scalability, mobility, reliability, security, timeliness, clustering, and localization synchronization strategies.

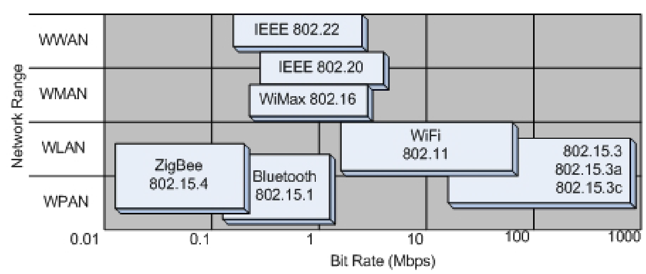


Fig. 1 - Wireless protocols overview

There are a wide range of wireless communication protocol standards (Fig. 1) for a wide range of applications (e.g. voice, video and general data communications), everyone of them setting a compromise between bit rate and radio coverage, according to the target applications scenarios (the personal, local, the metropolitan and wide). However there is a need for communication protocols that meet the needs of WSN applications. Overall, WSNs do not impose stringent requirements in terms of bandwidth, but they require low energy consumption so that network/nodes life time is prolonged as long as possible. In fact, meeting energy requirements are most often the main goal of WSNs protocols and technologies.

The IEEE 802.15.4 protocol [4] specifies the Medium Access Control (MAC) sub-layer and the Physical Layer. Though this protocol wasn't specially designed for WSNs, that provides the enough flexibility for fitting different requirements of WSN applications by adequately tuning its parameters. The ZigBee specification [5] relies on the IEEE 802.15.4 Physical layers and Data Link Layers, building up the Application and Network Layers, thus defining a full protocol stack for Low Rate Wireless Personal Area Networks (LR-WPANs). Figure 2 shows the layered architecture of the IEEE 802.15.4/ ZigBee protocol system.

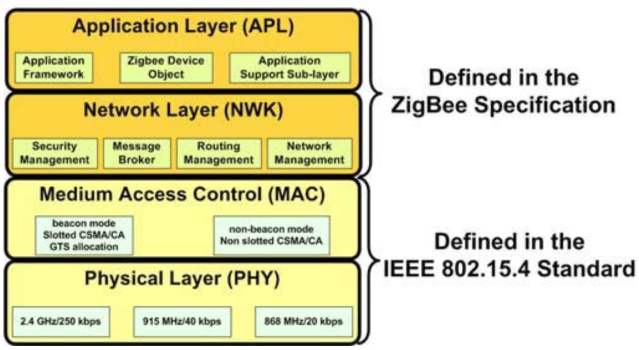


Fig. 2: The IEEE 802.15.4/ZigBee protocol stack architecture

ZigBee [6] is gaining an exponentially increasing interest from industry and academia, considered as a potential solution for low-cost low-power wirelessly connected monitoring and control devices [7-11]. This interest is mainly driven by a large number of emerging applications, including domotics (as the current principal commercial target of the ZigBee Alliance), health care monitoring systems, industrial automation, and environmental surveillance. The reputation of ZigBee, even though not widely commercially available yet, that is closely related to the objectives for which it was designed and to its flexibility to fit different network and application requirements. Whereas it was designed for low-cost and LR-WPANs, ZigBee is able to provide low energy consumption and real-time guarantees, which creates an eagerness for its application to WSNs.

II. Proposed Approach

The IEEE 802.15.4 standard is meant for the low energy consumption data transmission and the end to end performance play key role to save energy. The common packet loss or frame destruction need again same energy to retransmit the frame thus consumes lots of energy. If the system is encountered with less error probability the network live longer as it made for.

The proposed system is given in the figure below. The Zigbee technology works better with the Offset-Quadrature Shift Keying (O-QPSK) thus the existing system is implemented with the higher order spatial diversity technology to enhance the performance.

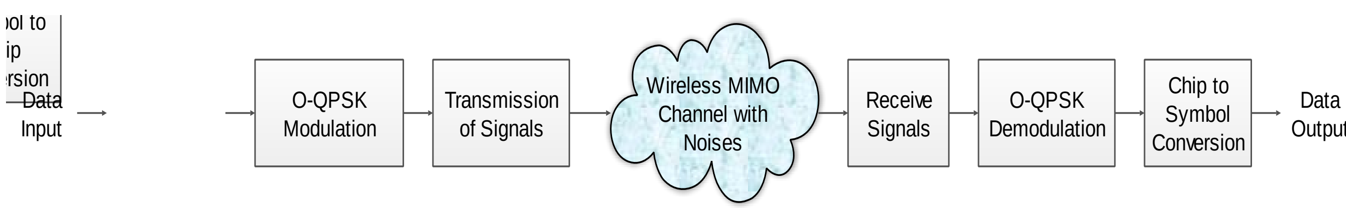


Fig. 2.1 Block diagram of the proposed IEEE 802.15.4 (Zigbee) with 8x8 and 16x16 spatial diversity

The major blocks of the systems is to convert symbols into chips and then modulate data followed by initialization of the MIMO AWGN channel to transmit data over. During transmission channel introduces noises in to the signal and signal become noisy and difficult to recover useful information. In such situations the spatial diversity has an added advantage by utilizing the space to reduce the error probability. Now at the receiver side the signal is detected and the demodulation process is performed and the chip sequence is then converted into symbols and finally got the data at the output.

The above explained proposed IEEE 802.15.4 with spatial diversity system is implemented on the simulation tool and the implemented algorithm is explained with the help of flow chart given in the Fig. 2.2.

The proposed algorithm execution steps are as follows:

a. *Starting of the simulation*
b. *Create simulation environment using variables*
c. *Generate data frame for transmission over network*
d. *Convert data symbols into chip sequence*
e. *Modulate the chip sequence with Offset-Quadrature Phase Shift Keying*

f. *Initialize MIMO-AWGN channel for better error probability (Spatial Diversity)*
g. *Generate noises which is being added during transmission through channel*
h. *Transmit signal through channel and add generated noise*

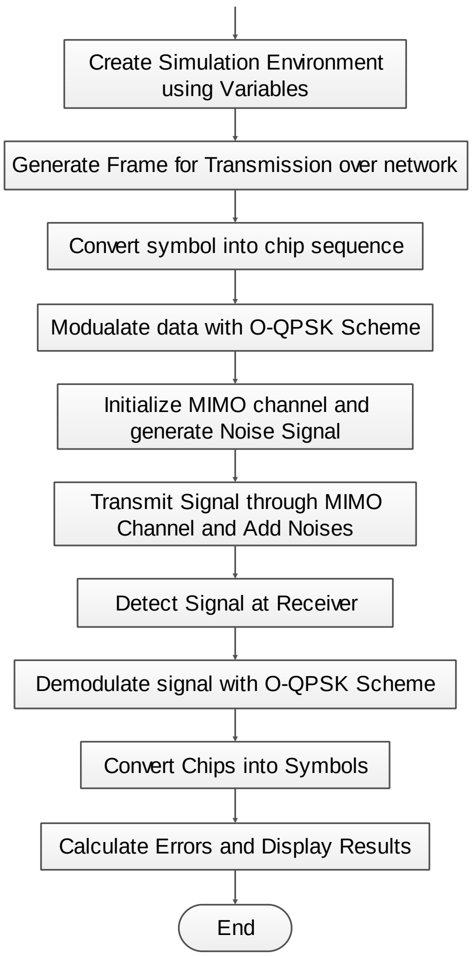


Fig. 2.2 Flow chart of the proposed IEEE 802.15.4 (Zigbee) with the spatial diversity

a. *Detect signal at receiver and the received signal is demodulated with Offset-Quadrature Phase Shift Keying*
b. *Convert chip sequence into data symbols*
c. *Calculate BER and the display results for various parameters*
d. *End of simulation*

III. Simulation Results

The Zigbee known for its low power data transmission network and this performance can be better if the error probability is reduced. To achieve the same a spatial diversity with higher number of transmitter and receiver antenna based system is proposed in this paper and the system with the implemented algorithm is explained in the previous section. The simulation results of the spatial diversity is shown in the figures below.

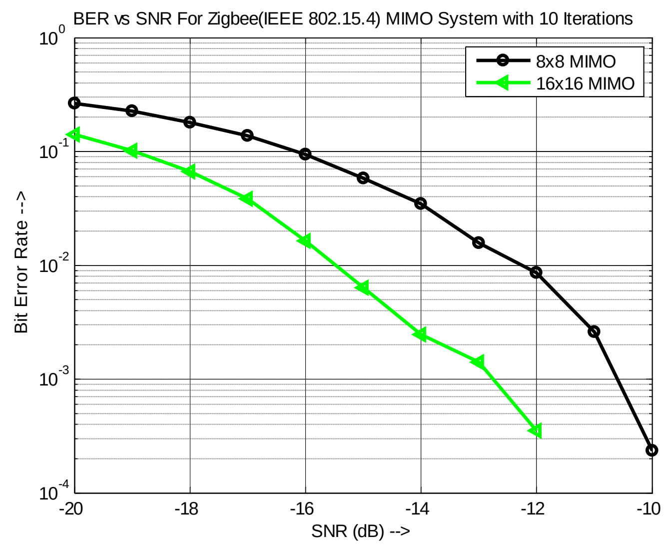


Fig. 3.1 BER vs SNR Curve of IEEE 802.15.4 (Zigbee) for 10 Iterations with 8x8 and 16x16 antenna configurations

In Fig. 3.1 the IEEE 802.15.4 system is simulated with the 8 and 16 transmitter antennas and 8 and 16 receiver antennas with 10 iterations and found that bit error rate of $10^{-3.9}$ range is achieved at -10dB which is low power as expected.

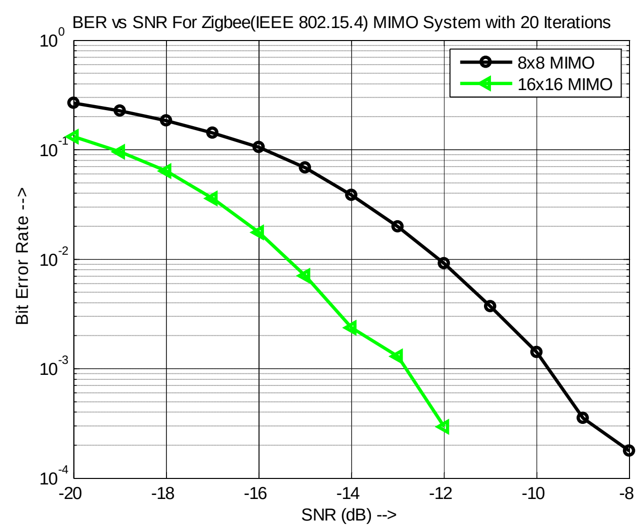
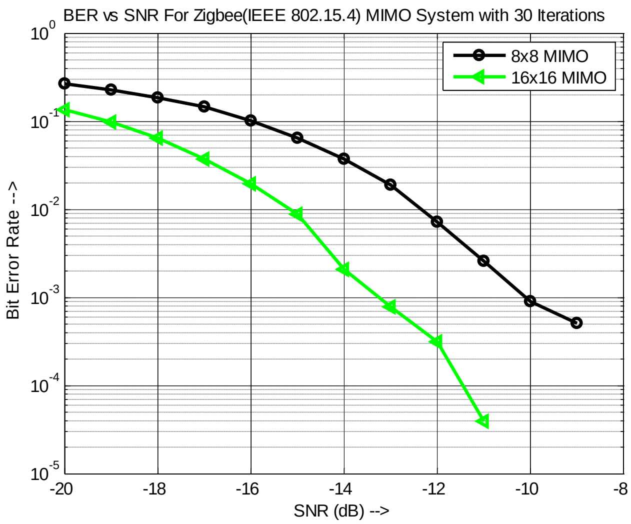


Fig. 3.2 BER vs SNR Curve of IEEE 802.15.4 (Zigbee) for 20 Iterations with 8x8 and 16x16 antenna configurations

In Fig. 3.2 the IEEE 802.15.4 system is simulated with the 8 and 16 transmitter antennas and 8 and 16 receiver antennas with 20 iterations and found that bit error rate of $10^{-3.95}$ range is achieved at -8dB which is low power as expected.

Fig. 3.2 BER vs SNR Curve of IEEE 802.15.4 (Zigbee) for 20 Iterations with 8x8 and 16x16 antenna configurations



In Fig. 3.3 the IEEE 802.15.4 system is simulated with the 8 and 16 transmitter antennas and 8 and 16 receiver antennas with 30 iterations and found that bit error rate of $10^{-4.5}$ range is achieved at -11dB which is low power as expected.

IV. Conclusion and Future Scope

The proposed Zigbee system with spatial diversity is simulated and the performance calculated in terms of BER for 0 to 20dB signal to noise ratio (SNR). From the results the lowest BER is achieved is $10^{-4.5}$ at -11dBs and this is lower power requirements for Zigbee standard. Now we can say that with the spatial diversity technique using two transmitter two receivers and with 4 transmitters and 4 receivers gives better performance with IEEE 802.15.4. The compared performance of the 2x2 and 4x4 configurations is found better with four antenna configuration.

In the future technologies improved modulation techniques makes system better with the filter implementations at the receiver reduce the errors to achieve optimum low power operations.

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