Adaptive Modulation and Coding for the IEEE 802.15.3c High Speed Interface Physical Layer Mode

Mohammed Amine Azza, Moussa El Yahyaoui and Ali El Moussati

Abstract Adaptive modulation and coding (AMC) is a technique that allows the adjustment of modulation and coding based on the quality of the transmission link, to achieve a transmission with higher data rate and better spectral efficiency. The purpose of this paper is to study the influence of AMC on the High Speed Interface Physical layer (HSI PHY) mode of the IEEE 802.15.3c standard. For this we have created a Simulink model representing the schema of the IEEE 802.15.3c transmitter/receiver with an algorithm which allows adaptation in terms of modulation and coding of the transmitter according to the link in accordance with a predefined script.

Keywords IEEE 802.15.3c · Adaptive modulation and coding · OFDM · 60 GHz

1 Introduction

The growth in the use of wireless devices has led to the improvement of the spectral efficiency to allow higher throughputs information. In traditional communication systems, the transmission is designed for a scenario facing variations of the channel, in order to provide an error rate lower than a specific limit. Adaptive character in transmission systems have been developed to solve the problem of variation in the quality of the transmission channel by adjusting the settings to take advantage of available resources by adapting the modulation, coding, transmission rate and other parameters to the conditions on the radio link (e.g. the path loss, the interference due to signals coming from other transmitters, the sensitivity of the receiver, the available transmitter power margin, etc.), to optimize the average spectral efficiency of the link.

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The AMC technique represents a tool, to increase the spectral efficiency of the radio channels [1], varying in time while maintaining a BER predictable, the order of modulation and Forward Error Correction (FEC) are modified by the coding rate adjustment for variations in the quality of the transmission channel. In the case of high attenuation, for example, a lower Signal-to-Noise Ratio (SNR), the size of the signal constellation is reduced to improve reliability, so a more robust transmission for an effective SNR. Conversely, low attenuation period or high gain, the size of the signal constellation is increased to enable significant modulation rates with a low probability of error, which has an immediate effect on the SNR.

This work falls within the framework of our study of Radio over Fiber (RoF) Systems; its main objective is to develop architecture able to adapt the transmission parameters such as modulation and coding type according to channel quality. For this purpose we have chosen to work on the IEEE 802.15.3c standard to design a model meets all the specifications of the standard and having the advantage of flexibility in terms of modulation and coding. The studied adaptation mechanism is taking into account transparency to the channel type, it allows the adaptation of modulation and FEC code rate regardless of the channel used, radio or optical.

To shed light on the importance of adaptability in terms of modulation and coding, we evaluate the performance of our transmission system before and after the introduction of the AMC mechanism. So, we developed a simulation environment MATLAB/Simulink. First, according to the standard specifications, a model of HSI PHY of IEEE 802.15.3c (TG3c) [2] was designed. Then we went to work on an innovative technique that allows to adapt in terms of modulation and coding with the variations of the transmission channel, while ensuring full transparency against the channel type, to reach our main objective to having a transmission system with high spectral efficiency and stability in terms of transmission quality in the presence of channel variations, and whatever the type of this latter.

2 High Speed Interface Physical Layer HSI PHY of IEEE 802.15.3c Standard

Several reasons justify the attention we have given to the 60 GHz technology, it is clear that this latter offers various advantages over nowadays communication systems. The main reason is the huge and continuous unlicensed bandwidth available; this huge bandwidth provides good solutions in terms of capacity and flexibility. Add to this that the regulation of this band allows a relatively higher transmission power to overcome the greater path loss at the frequency of 60 GHz [3]. Another advantage presented by the 60 GHz technology is the spectral efficiency, and also the ability to support very high data rate applications with a simple modulation.

The interest of 60 GHz radio does not cease to grow especially with the emergence of several international mm-wave standards groups and industry alliances, we find among others, the IEEE 802.15.3c [2] working group (TG3c) which

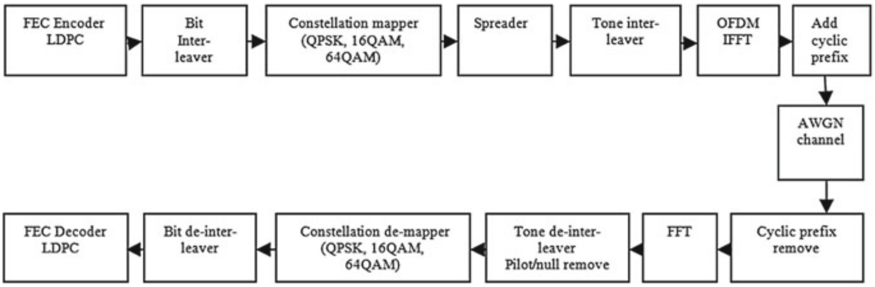

Fig. 1 HSI PHY mode of IEEE 802.15.3c block diagram

was formed to develop an alternative physical layer (PHY) mm-wave for the existing IEEE 802.15.3 WPAN standard 802.15.3-2003, there's also the ECMA TC-48 [4], which began an effort to standardize Medium Access Control (MAC) and PHY for high-speed, last but not least, the Wireless Gigabit Alliance (WiGig) [5] formed in May 2009 to establish a unified specification for 60 GHz wireless technology to create a truly global ecosystem of interoperable products for a wide range of applications (Fig. 1).

As mentioned above, our recent work is based on the IEEE 802.15.3c standard which is the first IEEE wireless standard for data rates over 1 Gb/s. According to the report of TG3c, three PHYs are defined for the mm-Wave PHY, namely single carrier (SC) PHY, high speed interface (HSI) orthogonal frequency division multiplexing (OFDM) PHY and audio video (AV) OFDM PHY. We made the choice to focus our work on second mode HSI PHY, designed for high speed bidirectional data transmission and uses OFDM with an FEC based on LDPC.

The figure above shows the block diagram of the design of HSI PHY mode in Simulink. At first, random data bits are generated and then coded by two LDPC encoders with FEC rates of 1/2, 3/4 and 5/8, the output of LDPC encoder multiplexed to form a single data stream. After the data multiplexer, the bits are interleaved by a bloc inter-leaver. The coded and interleaved bits can be modulated using QPSK, 16QAM and 64QAM modulation. Subcarrier constellations consist of QPSK, 16-QAM, and 64-QAM. Each group of 336 complex numbers are assigned to an OFDM symbol. In each symbol OFDM DC, null, and pilot tones are inserted before the tone inter-leaver. Tone inter-leaver makes sure that neighbouring symbols are not mapped into adjacent subcarriers. The interleaved tones are modulated by OFDM modulator that consists of 512-point IFFT. Finally, a cyclic prefix of 64 tones is inserted to keep the OFDM system from inter-symbol and inter-carrier interferences, and then symbols are transmitted.

At the reception, cyclic prefix is removed from the received signal and then demodulated by OFDM that consist of 512-point FFT. After de-interleaving process, data carriers are identified and QPSK, 16QAM or 64QAM symbols are demodulated by the de-mapper block. The obtained bit stream is de-interleaved and demultiplexed into 2 bit streams to be decoded with 2 LDPC decoders. Different modulation and coding schemes used parameters are given in Table 1.

Table 1 HSI PHY MCS used dependent parameters

MCS index	Data rate (Mb/s)	Modulation scheme	FEC rate
1	1540	QPSK	1/2
2	2310	QPSK	3/4
4	3080	16-QAM	1/2
5	4620	16-QAM	3/4
7	5775	64-QAM	5/8

3 Adaptive Modulation and Coding AMC

As mentioned in the introduction, adaptive modulation and coding is a technique that targets a better use of available resources in a communication system [6], with minimum error probability. Its a technique to adapt and adjust, in real time, the transmission parameters according to the quality of the link (Fig. 2).

At this level, we introduced a channel estimation system (red boxes) with a feedback path between the estimator and the transmitter to which the receiver returns information to the channel state for adapting modulation and coding. The transmitter expects the receiver the channel estimation results to select one of the preset MCSs modes for the next transmission interval. Note here that our adaptive system requires tremendous variations in channel quality, and must also make sure that there's not a huge delay between the estimation of the quality and the actual transmission to ensure effective operation of this system.

The channel estimation metric used is the SNR. For estimating SNR at the reception, we chose a simple method among several available [7]. A real time estimator which is adapted to all types of modulation used is developed. As well known, the SNR is the ratio between the signal and the noise powers.

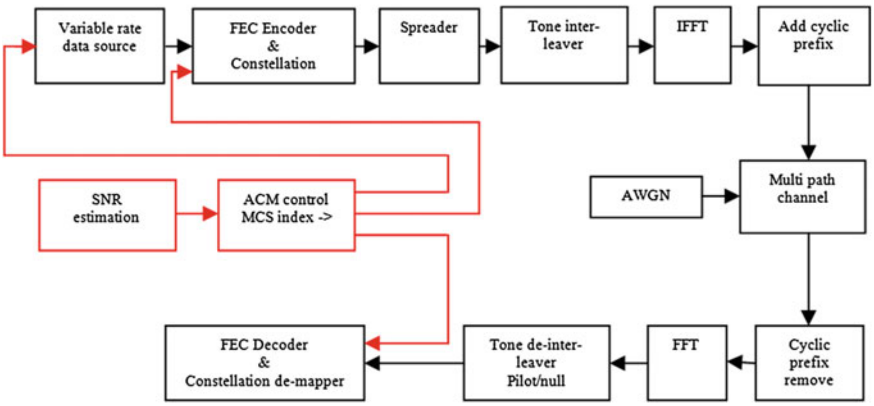

Fig. 2 AMC system and HSI PHY mode of IEEE 802.15.3c block diagram

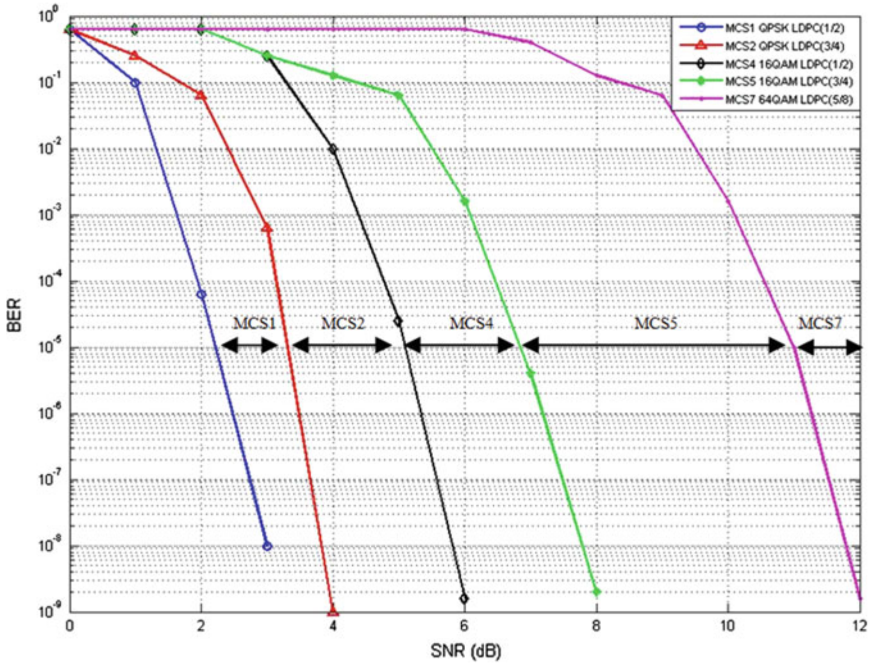

Fig. 3 BER versus SNR thresholds and corresponding to the N = 5 MCS used by the AMC

SNR = S/N, where *S* represents the average signal power, and *N* is the average noise power which can be calculated from the noise variance, σ^2.

The choice of the appropriate modulation and coding scheme (MCS) for use at a new transmission, is realized at the AMC control block based on the prediction of the channel status. An SNR threshold ensures a BER below a limit value BER0, which is defined by the system for each method whenever the SNR is above the threshold.

From the BER, SNR thresholds are achieved according to their characteristics for a modulation and coding scheme on an AWGN channel. As described in Fig. 3, this method consists in cutting the SNR range in N + 1 sub regions (N is the number of modulation and coding schema used by the AMC method, in our case N = 5), N + 2 thresholds which we translate as.

Each of N schemes is then used to operate in a particular area of the SNR. When SNR value is within an area, the information associated with the channel status is sent to the AMC control block which then adapts and requires the transmitter a transmission rate, the encoder encoding type and chosen a method of modulating guaranteeing a BER below the threshold BER0. This allows the system to transmit data with high spectral efficiency when the SNR is high and reduced when the SNR is low.

The AMC control block has the function to detect the crossing of decision thresholds for determining the method of modulation and coding to be used in the next frames sent by returning this information not only to the transmitter but also to the receiver.

4 Test and Results

For our tests, we have considered the HSI PHYs MCSs parameters presented in Table 1. The signal through the channel is disturbed by AWGN. Thus, the receiver receives a signal with a time-varying channel signal to noise ratio CSNR thing that affects the total SNR at the reception.

The curves shown in Fig. 3 correspond to different modulation methods and coding permitted by the HIS PHY mode of IEEE 802.15.3c system, MCS1, MCS2, MCS4, MCS5, and MCS7. They were obtained from simulations assuming an accurate knowledge of the coefficients of the AWGN channel. The entire adaptation (switching) threshold are obtained by reading SNR points corresponding to a $BERthreshold = 10^{-5}$.

Figure 3 shows the BER versus SNR curves of 5 encoding and modulation schemes with the margins of use of each scheme mentioned with arrows. The points of switching between MCS are fixed by the BER threshold. From the case where

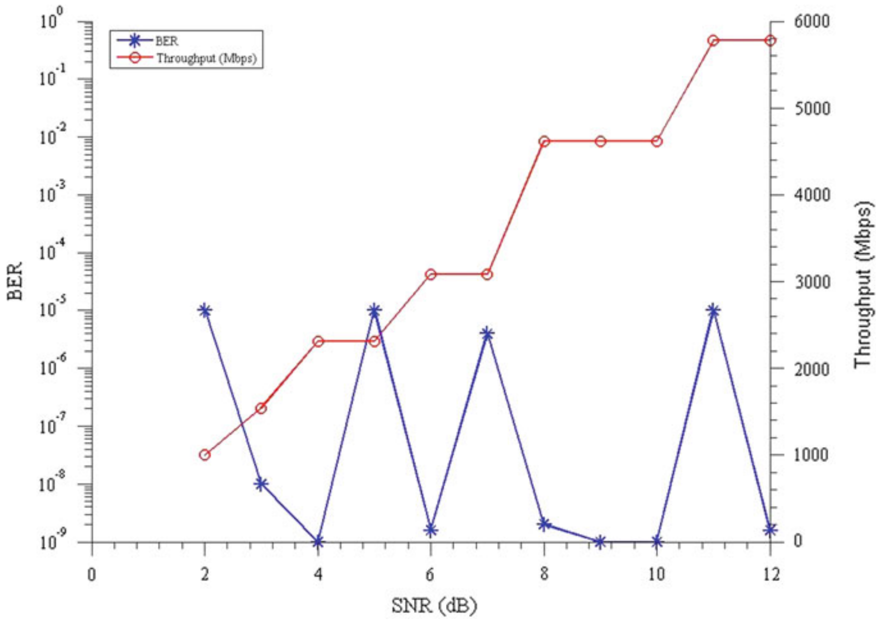

Fig. 4 Curves of BER versus SNR and throughput variation for the AMC method

the SNR is higher (SNR between 10 and 11 dB), we use the modulation and coding scheme MCS7 guaranteeing a BER below the BER threshold, when the estimated SNR at the reception increases, a switch to the next scheme MCS5 is immediately made, and so on until we get to use the first scheme MCS1 in the SNR margin between 2 and 3 dB.

The variation of SNR at the reception due to CSNR variation, introduces a change in the modulation and coding scheme used, which causes a throughput variation as shown in Fig. 4. It can be noticed that with a high SNR levels we can transmit data with fairly high throughput, degradation in the quality of the link causes a change of MCS used to keep an acceptable BER level, but this time with less throughput.

5 Conclusion

In the present paper, a solution of adaptation in terms of modulation and coding for the HSI PHY mode of the IEEE 802.15.3c has been proposed and studied. 5 schemas modulation and coding were used with three different types of modulation (QPSK, 16QAM, 64QAM) and variable FEC rate. The IEEE 802.15.3c model and simulations were made on Matlab/Simulink.

The main conclusion drawn from the results obtained that the adaptive telecommunication systems have an advantage over the conventional system with fixed coding and modulation schemes; this advantage is the spectral efficiency and the stability of the transmission quality against the channel variation.

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