



A novel Trellis Coded Modulation scheme for robust transmission of Prioritized H.264/AVC Video employing Alamouti's code for wireless MIMO systems

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Abstract: Recently, there has been an increasing demand for high data rate communications for wireless technologies. With the integration of these technologies and multimedia services, transmitting high quality image and video has become one of the main objectives for the present and next generations of multimedia wireless network systems. In this research work, it is proposed to apply prioritized Trellis Coded Modulation (TCM) scheme employing Alamouti codes to H.264/AVC video bitstreams for increased robust transmissions over MIMO channels. The channel data rate is kept constant at 1Mbps whilst the source rate is varied according to the TCM Alamouti code rates. In this work the inherent UEP capability of the H.264/AVC video bitstreams at the application layer is applied in order to have more robust transmission. All implementations are carried out using MATLAB R2013^R Simulink^R and Cygwin. It is shown that in MIMO channels the Alamouti scheme outperform the corresponding scheme employing only TCM.

Keywords: Unequal error protection, Trellis Coded Modulation, Alamouti Code, MIMO channels, H.264/AVC prioritization.

I. Introduction

As bandwidth is a limited resource in wireless channels, and there are lots of factors affecting the channel, there is a need to maximize channel performance. Mobile phone relies on wireless data transmission mostly, and smart phones nowadays consumes primarily multimedia content, so this work focuses on how streaming a video on a wireless system in real life can be affected by many complex factors.

Trellis Coded Modulation is a modulation scheme designed by Gottfried Ungerboeck [1]. A convolutional encoder of rate $\frac{1}{2}$ will take 1 bit and output 2 bits digitally, following which the output bits are modulated into an analog signal via a carrier to be transmitted. TCM combine both the digital function and analog function into one [2,3]. Ungerboeck noted that design should maximize the free Euclidean Distance (ED) which is not the case when using a Gray coding mapping scheme. He further improved the codes by proposing to map signals known as "set partitioning" aiming at maximum free ED [4].

Alamouti codes makes use of an array of antenna to maximize data rate and reliability [5,6]. It sends copies of the same symbol on different antenna and also conjugates of the packets at the next time interval. So at the receiver, using channel state information, the symbols are decoded back with a high success rate. MIMO is a new wireless technology that uses multiple antenna to transmit and receive data at the same time [7-9]. This technology forms the base of fast wireless standards, the IEEE 802.11n, Long Term Evolution and WiMAX. The optimal system is where both the transmitter and receiver supports MIMO and was first described by Gerard Foschini [6] and others [7,8]. Where multipath propagation were causing interference and degradation to signals in other systems, MIMO takes advantage of that natural wave properties. Smart antennas are used with spatial diversity technology to capture the different signals.

H.264 is part of the H.26x family of standards by the Video Coding Experts Group (VCEG), a subset-working group of the International Telecommunication Union (ITU-T). The final draft of the standard was over in 2003 and maintained jointly by the ITU-T and the ISO/IEC MPEG, which names H.264 as MPEG-4 Part 10 or AVC (Advanced Video Coding). To refer to the partnership to develop this standard, it is referred as MPEG-4/H.264 AVC [10]. Also mostly known as MPEG-4 in marketing terms and in consumer products. It is an industry standard for video compression for storing and transmitting [11].

In this paper we propose a novel TCM scheme to transmit H.264/AVC data over a MIMO channel employing Alamouti code and 8PSK modulation. Simulation results show that compared with conventional TCM scheme, the proposed approach provides more effective video transmission through the MIMO wireless channel.

The remainder of this paper is organized as follows. Section 2 briefly introduces the H.264/AVC standard along with a packet priority assignment schemes. Section 3 outlines the coding concepts associated with Trellis-Coded Modulation and Alamouti Coding concept. In Section 4, we describe the processes involved in the design and

implementation associated with the proposed scheme. Section 5 explains the experimental set-up and presents the simulation results as well as discussions for the proposed work and finally, Section 6 concludes the paper.

II. H.264/AVC Prioritization

H.264 standard consist of a Video Coding Layer (VCL) translating video information into bit stream and Network Abstraction Layer (NAL), maps and packetize the bitstream into units for transmission [11]. When using Data Partitioning (DP) mode, all VLC with the same data type are put together in each frame. DP A contains the residual motion vectors, Macroblock amongst others and is the most important part whilst DP B is called intra-frame segmentation loading the coding mode and the coefficients in the intra-frame blocks. Inter-frame segmentation is called DP C, it only includes coding mode and coefficient in inter-frame block. DP C is the biggest segmentation but DP B is more effective. If during a transmission, DP A is corrupted but not DP B or DP C, then the whole data is discarded. A slice can be decoded with only DP A and DP B information [12]. H.264 video source can be organized in packets depending on the importance of the frame type, DP type and slice group. Therefore, we can group the important data in a packet with higher priority and giving it more protection. A group of picture (GOP) specifies in which order the intra and inter frames are arranged., the H.264 bitstream is split into three priorities, with the Data partitioning 'ON' and the data of each GOP is differentiated based on the frame type and DPs. The three priority queues at the application layer has been designed to accommodate unequal error protection and are as follows [12]:

- ❖ Priority 1 Queue
 - IDR – frame
 - DP A of I – frame
 - DP B of I – frame (if queue 1 can accommodate else move data to 2nd queue)
- ❖ Priority 2 Queue
 - DP A of P – frame
 - DP A of B – frame
 - DP C of P – frame (if queue 2nd can accommodate else move data to 3rd queue)
- ❖ Priority 3 Queue
 - DP C of P – frame
 - DP B of B – frame
 - DP C of B – frame

III. Trellis Coded Modulation and Alamouti Code

TCM has both a digital coder (Trellis code) and an analog (constellation mapper) part. Setting $k = 2$, the code rate becomes $2/3$, transforming a QPSK signal into an 8PSK signal. The advantage in that is the bandwidth remains unchanged as only the number of constellation points that doubles [1,4]. Fig. 1 shows the block diagram of a general TCM encoder and Fig. 2 illustrates the representation of a QPSK signal on a 8-PSK constellation diagram. Using convolutional code, TCM achieves a highly efficient bandwidth modulation. For the same symbol rate, it can increase the bit rate by doubling constellation points. Coding gain is the measure of performance over an uncoded signal and Euclidean distance is used as the decoding metric. Fig. 3 shows some TCM schemes employing various convolutional codes as well modulation schemes.

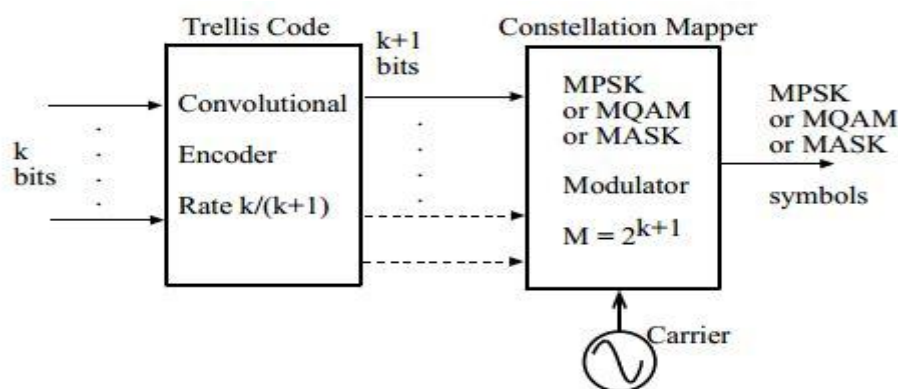


Fig. 1: Convolutional encoder ($k/k+1$) and Constellation Mapper (2^{k+1})

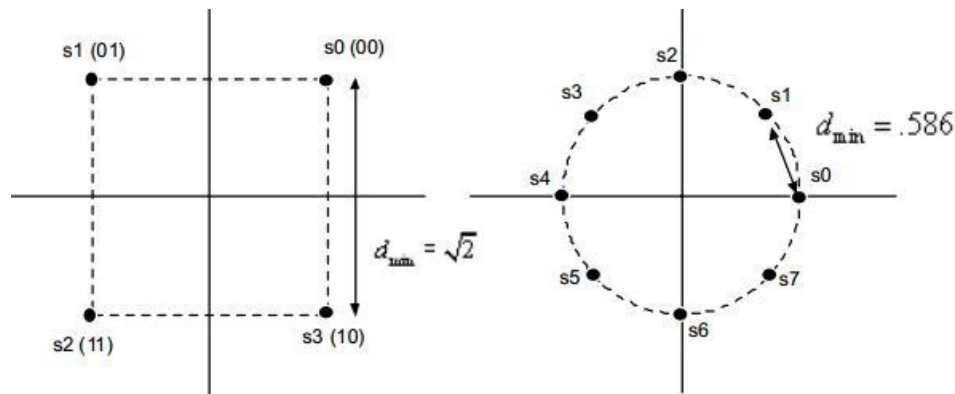


Fig. 2: QPSK signal using 8PSK constellation

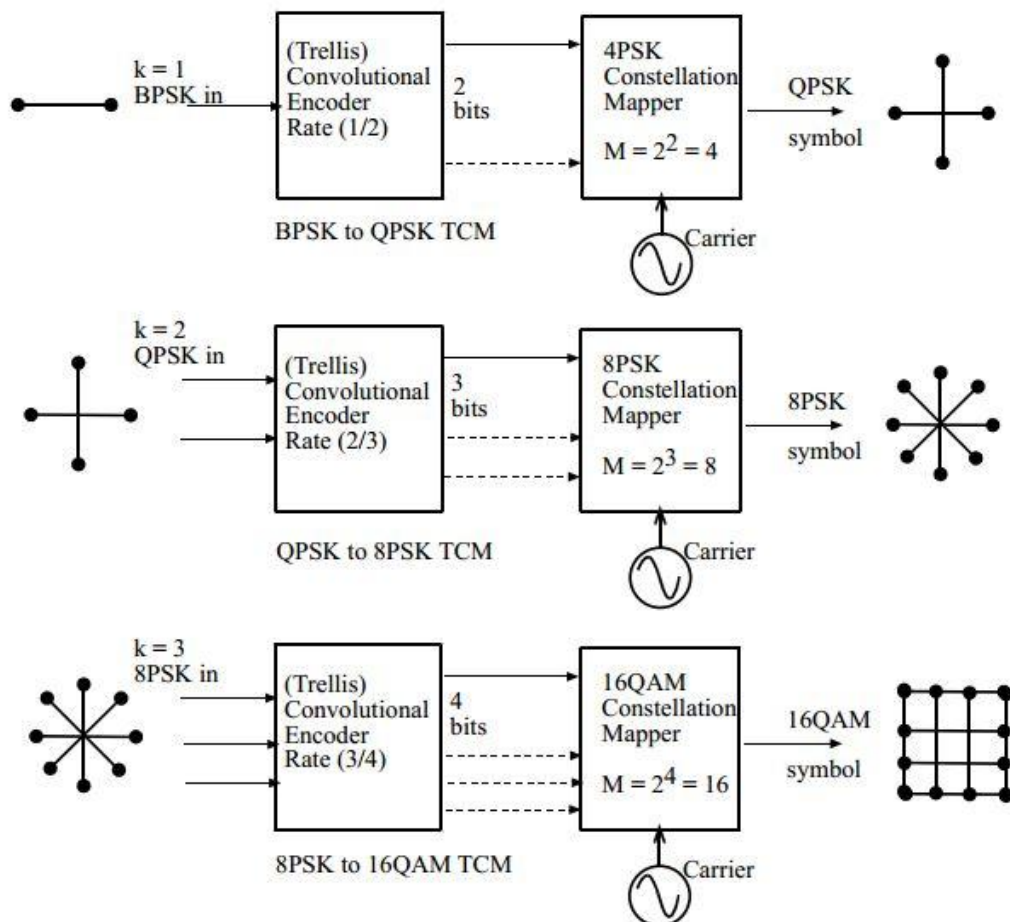


Fig. 3: BPSK (rate = $\frac{1}{2}$); QPSK (rate = $\frac{2}{3}$); 8PSK (rate = $\frac{3}{4}$)

MIMO designs are classified as either using diversity techniques or spatial-multiplexing techniques but both are present in a MIMO system [8]. Diversity techniques means that the same data gets transmitted over multiple antenna to travel on diverse paths before reaching the receiver, thus increasing reliability [9].

Spatial-multiplexing techniques, similar to the idea of OFDM, the data is multiplexed on the different channels, increasing data throughput at the cost of diversity gain [8]. In a SISO system, channel knowledge is given only by its constant SNR value. Assuming a 2x2 transmitter and receiver, and the same symbol is transmitted from each antenna, then there exist four possible paths with an associated gain/loss. Since the same symbol goes on all four paths, this makes up for any weak link if present. Therefore as number of antenna increase, we may observe the fading channel shaping into a Gaussian channel.

To obtain diversity gain, we assumed MIMO links to transmit the same symbol, but if different symbols could be transmitted on the same antennas, there can be a balance between data rate gain and diversity gain. The gain in data rate is termed Spatial Multiplexing Gain (SMG) for a MIMO system. SMG depends on number of NT

and NR and is equal to the lowest value of the two if there is unequal number of antennas. Spatial multiplexing gain is given by equation (1), where s is the data rate as SNR increases [8].

$$s = \lim_{SNR \rightarrow \infty} \left(\frac{r}{\log(SNR)} \right) \quad (1)$$

Space-Time Coding (STC) has various ways to obtain SMG of a link. The goal is to have the optimum gain for the system [7,8]. We get two classification of STC.

- Space Time Trellis Codes (STTC): Similar to using trellis and convolutional code of SISO channels but here, using multiple antennas. The coding gain is at the expense of highly complex decoding.
- Space Time Block Codes (STBC)

Alamouti [5] came up with a simple STC in his 1998 paper. Consider Alamouti block code of a 2x1 system. That is $N_T = 2$, and $N_R = 1$. He transmitted two different symbols, S_1 and S_2 using the different antennas, thus having a rate of 2 bits per unit time. As mentioned above, it is the multiplexed gain. To achieve diversity gain, at the next time interval, each antenna transmit the conjugate of what they transmitted at time interval 1 but antenna one negates the signal. This is illustrated below, where rows represents antenna and columns represents time index.

$$S = \begin{bmatrix} S_1 & -S_2^* \\ S_2 & S_1^* \end{bmatrix} \quad (2)$$

Not considering noise, and taking k as a time index and h_{ij} as the channel impulse response, the signal are

$$r_1 = h_{11}S_1 + h_{12}S_2 \quad (3)$$

$$r_2 = -h_{11}S_2^* + h_{12}S_1^* \quad (4)$$

Only the receiver need to know the channel state informations, h_{11} and h_{12} through estimation or training. We get an estimate of S_1 by first multiplying r_1 by h_{11}^* and r_2 by h_{12}^* .

$$\begin{aligned} h_{11}^* r_1 &= |h_{11}|^2 S_1 + h_{11}^* h_{12} S_2 \\ h_{12}^* r_2 &= -h_{11} h_{12}^* S_2^* + |h_{12}|^2 S_1^* \end{aligned} \quad (5)$$

Re-arranging equation (6) and dividing by $|h_{11}|^2 + |h_{12}|^2$

$$S_1 = \frac{h_{11}^* r_1 + h_{12} r_2^*}{|h_{11}|^2 + |h_{12}|^2} = S_1 \quad (7)$$

For estimate of S_2 , multiply r_1 by h_{12}^* and r_2 by h_{11}^*

$$S_2 = \frac{h_{12}^* r_1 - h_{11} r_2^*}{|h_{11}|^2 + |h_{12}|^2} = S_2 \quad (8)$$

One receive antenna gives a diversity gain of about 8.5 dB over a SISO channel. If a second antenna is added, the gain is greater.

IV. Proposed system design and Implementation

In this work, MATLAB R2013^R Simulink^R is used to design the proposed TCM scheme. Fig. 4 below shows the complete design model. It is proposed to divide the bitstream into three priorities and apply equal TCM coderate encoders to each priority for different packets. The Orthogonal Space-Time Block Codes is present in the Simulink library, it maps symbols to multiple antennas.

From the design of Fig. 4 the Bernoulli Binary Generator generates a bitstream and a demultiplexer is used to split the bitstream into 3 priorities which are fed to TCM encoders of rate 1/3. A fading channel will be used after the Alamouti encoding to simulate the attenuation due to environment that a wireless signal is subjected to. The modulated signal is then fed to the wireless baseband multipath Rayleigh fading channel with Doppler frequency of 500 Hz. The Jakes model is chosen because it is a deterministic model and the signal scatters uniformly across the medium and emerge uniformly at the receiver side. The Rayleigh Multipath Fading includes complex path gains which need to be removed from the signal. The block consists of a circuit which removes the gain occurred during multipath and converge all signal onto one resulting signal. Additive White Gaussian Noise (AWGN) is then added to the faded signal resulting in a corrupted one. The Signal to Noise Ratio per bit or E_b/N_0 in this block is varied to measure the performance of our design. At the receiver side demodulation of the signal is carried out using hard decision followed by the decoding of the TCM decoder.

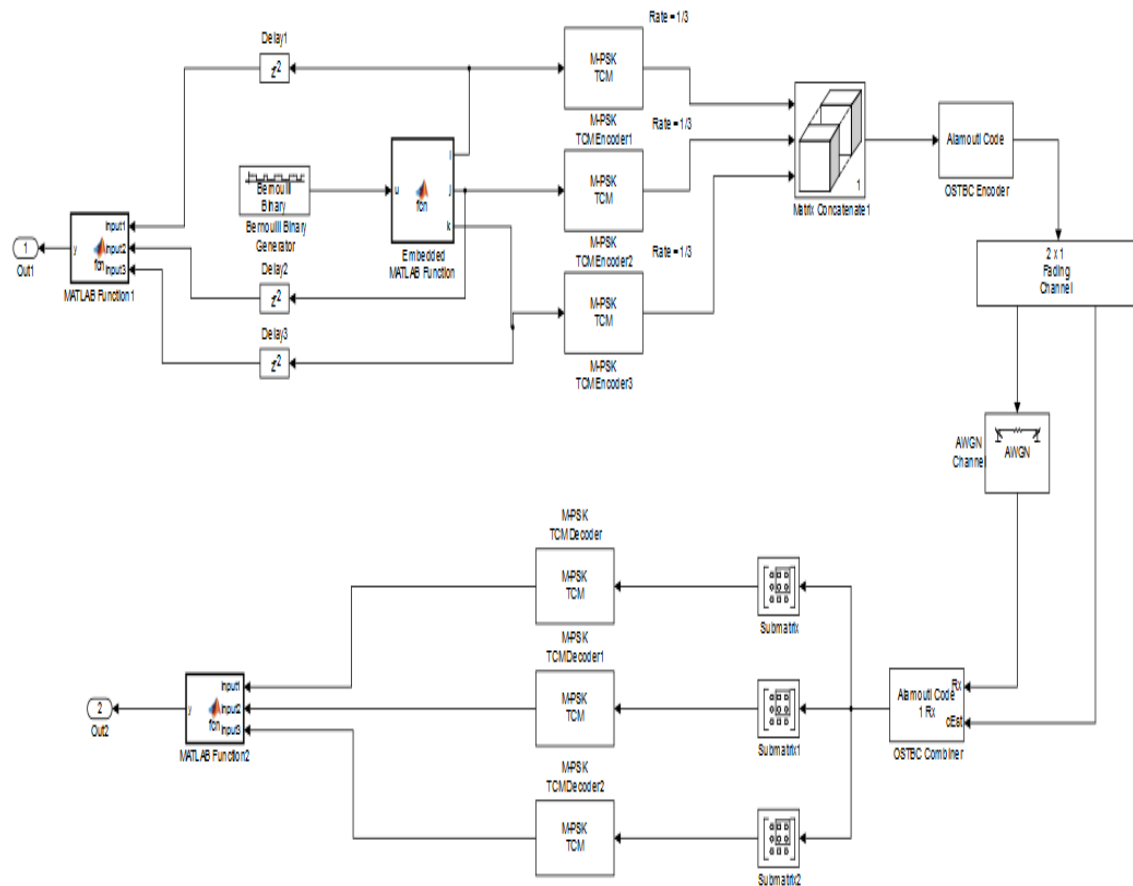


Fig. 4: Proposed system design in Matlab R2013a Simulink

VI. Simulation results and discussions

The experiment is set up by using the H.264/AVC Annex B (JM14.1) reference source code [1] for encoding the CIF (352x288 pixels) Bus video test sequence at a bitrate of 512 Kbps. The video sequence was encoded at 30 frames/second for a GOP of 12 frames (IDR B P B P B P B P B P B I ...) with IDR rate of 24 frames. The following error resiliency features was enabled: data partitioning, FMO dispersed mode and Constrained Intra Prediction. The NAL size of 200 bytes was considered. A robust decoder with error concealment schemes is used [10].

Two channel models namely Rayleigh and AWGN have been used in the simulations. The built in AWGN and Rayleigh MATLAB R2013a Simulink channel models, from the communications blockset, were used. For simulations Visual studio 2010 is used to compile H.264/AVC source code, MATLAB R2013a Simulink to simulate the physical layer and Cygwin to automate the complete system.

Fig. 5 shows the video performance achieved with varying Eb/No. It can clearly seen that as the signal to noise ratio per bit sent for the video bitstream is increased there is a corresponding increase in the video performance that is Peak Signal to Noise Ratio (PSNR).

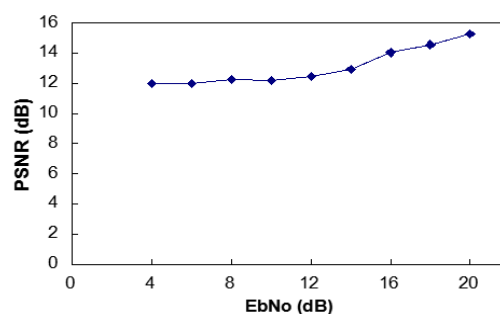


Fig. 5: PSNR performance with varying Eb/No for the video Bus sequence

The performance of our designed TCM scheme employing only Rayleigh channel together with the Alamouti code in MIMO channels are presented in Fig. 6 in terms of test frame sequences. It can be observed that the TCM scheme employing MIMO channels outperform that of the scheme with only the TCM alone. A gain of around 1 dB in PSNR is observed in this case, which makes our proposed design useful for many MIMO applications.

Original Bus Sequence



TCM - Rayleigh : EbNo=20 dB, PSNR =15.3 dB



Alamouti and TCM- MIMO channel : EbNo=20 dB, PSNR =16 dB



Fig. 6: Test video sequences (Bus) for the proposed TCM scheme with MIMO applications

VI. Conclusions

In this paper, we developed a Trellis-Coded Modulation scheme, by jointly using the prioritized TCM as well as Alamouti codes at the physical layer, for robust transmission of prioritized H.264/AVC video packets over error-prone MIMO wireless channels. It was shown through simulations that our TCM scheme performs better than a TCM scheme without MIMO capabilities. We observed that a 1 dB gain in PSNR is achieved over the case for only the TCM without MIMO channels. This design can find suitable applications for MIMO channels.

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