Wirelesshd Video Transmission Over Multicarrier Error-Correctionchannels

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ABSTRACT

Uncompressed High-Definition video streaming over extremely high frequency using wireless technologies, also known as WirelessHD, is a challenge problem because of the high data rate requirement and channel variations. The advantages in RF technology and the huge bandwidth available in the 57-66 GHZ millimeter wave open new era for High Definition applications and high data rates communication. Retransmission is not favored for HD multimedia transmission as any latency may cause flickering. So, powerful error correction and detection is needed to detect any corrupted pixels and recover it to guarantee the communication. In this study, we proposed a system that uses Low Density Parity Check (LDPC) code for error detection and correction and OFDM technique for protecting video signal from fading. A suggested frame partitioning technique is applied to perform spatial diversity.To judge on the proposed system, peak signal to noise ratio and symbol error rate will be used at the receiver for testing the received frame quality. Simulations using uncompressed videos indicate that the proposed system can give low bit error rate and high peak signal to noise ratio after transmitting the frame over AWGN and Rayleigh channels.

Keywords: Low Density Parity Check (LDPC), High-Definition (HD), Inverse Fast Fourier Transform (IFFT)

1. INTRODUCTION

Wireless connectivity became a de facto technology in consumer communications and networking. Wi-Fi, Ultra Wideband (UWB), home RF and Bluetooth are examples of such wireless technologies reducing the wiring dilemma facing multimedia home networks. In addition, standard multimedia applications, High-Definition (HD) and 3D video streaming are of great challenge in processing as well as in transmission. Current local and home area wireless technologies (Guo *et al*., 2011) can support less than 1Gbps data rate. High Definition Multimedia Interface (HDMI) can deliver uncompressed video and supports high data rate applications such as, HDTVs, Blu-ray players, gaming systems and digital cameras, but cables are needed for interconnection between devices (Wu *et al*., 2010). Therefore, a new system is required to achieve a wireless version of HDMI. Moreover, compression at the transmitter and decompression at the receiver possess problems in wireless multimedia applications starting with the processing time of compression and decompression to degradation in picture quality at the receiver and ending with transcodes that convert compressed HD videos from compression format to another. Hence, multi-gigabit wireless solutions are required. Those new systems must achieve high bandwidth, error resilience, no retransmission, immunity to channel variations, low cost and low power consumption. The 60 GHz technologies are candidates for huge rate transmission in homes and local area networks due to the availability of ultra wide bandwidth, small coverage area, directional antenna and line of sight advantages.

Working at the 60-GHz frequency is a challenging issue due to the very high attenuation that the signal will suffer and relatively high erroneous rate yielding to undesirable disturbance in multimedia communication.This study proposes a new system that is suitable for supporting uncompressed high-definition multimediatransmission intended for home applications and WirelessHD (Lawton, 2008). A new preprocessing technique called frame partitioning is proposed followed by OFDM and Low Density Parity Check (LDPC) coding technique.

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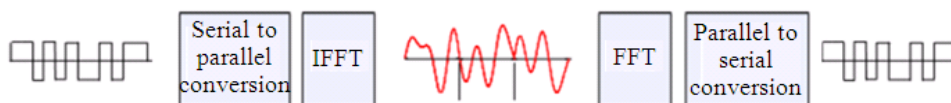
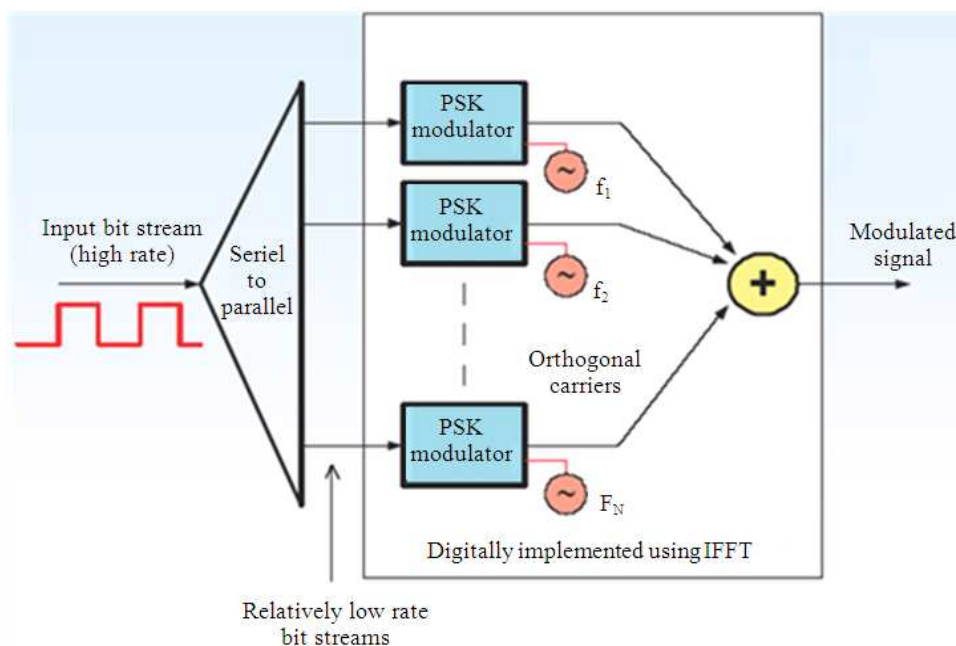**Fig. 1.** IFFT and FFT usage for implementing OFDM system

Fig. 2. OFDM modulator

1.1. Orthogonal Frequency Division Multiplexing and Low Density Parity Check

In OFDM, the signal is split into number of independent orthogonal sub-channels, modulated and then re-multiplexed to create OFDM carrier (Hamdi, 2011). Bit stream is split into parallel sets of data. Each parallel set of data represents a sub-channel. Sub-channels are modulated in an orthogonal way to prevent interference between them. Inverse Fast Fourier Transform (IFFT) is used to perform this orthogonality condition at the modulator. Fast Fourier Transform is used at the receiver to return all parallel channels to their baseband form. **Figure 1** illustrates the basic communication system with the position of IFFT and FFT while **Fig. 2** illustrates the OFDM modulator.

OFDM splits the whole signal bit stream (higher bit rate) into a number of parallel independent channels (lower data rate). This gives the advantages of minimizing the amount of dispersion caused by multipath delay spread and any blockage in a certain sub-channel due to noise will not affect the others. Also, using IFFT and FFT for implementing OFDM modulation and demodulation for digital communication make its implementation easy, fast and cheap using DSP off the shelf chips.

Low Density Parity Check is a channel coding that adds redundancy bits used for error detection and correction (Ahn and Yang, 2010). Gallager (1962) invented the Low-Density Parity Check Code (LDPC) that achieves the target of a random but systematic code, enabling near Shannon-limit performance. However, these codes were not used for over 30 years due to the computational effort in implementing the encoder and decoder of such codes. Low-Density Parity-Check (LDPC) codes are a class of linear block codes. The name comes from the characteristic of their parity-check matrix and the term low density stands for the few number of 1's in comparison to the amount of 0's in the matrix. LDPC codes are used for error detection and correction which give a reliable communication between transmitter and receiver with minimum number of retransmissions.Basically there are two different possibilities to represent LDPC codes. Like all linear block codes they can be described via matrices. The second possibility is a graphical representation (Zheng *et al.*, 2011).

$$H = \begin{bmatrix} 0 & 1 & 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 \end{bmatrix}$$
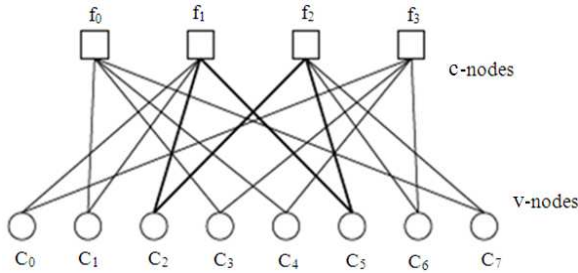
Fig. 3. Parity check matrix

Fig. 4. Bipartite graph

The matrix defined in **Fig. 3** is an example of a LDPC parity check matrix with dimension (n×m) for a (8, 4) code. Tanner introduced an effective graphical representation for LDPC codes. This graphical representation helps to describe and perform the decoding algorithm. Tanner graphs are bipartite graphs. That means the nodes of the graph are separated into two distinctive sets and edges are only connecting nodes of two different types. The two types of nodes in a Tanner graph are called variable nodes (v-nodes) and check nodes (c-nodes).

Figure 4 is an example for Tanner graph and represents the same LDPC code in **Fig. 3.** The creation of such a graph is quite simple. It consists of m check nodes (the number of parity bits) and n variable nodes (the number of bits in a codeword). Check node f_i is connected to variable node c_j if the element h_{ij} of H is a 1. The feature of LDPC codes to perform near the Shannon limit of a channel exists only for large block lengths.

Since the complexity grows in $O(n^2)$, even sparse matrices don't result in a good performance if the block length gets very high. So iterative decoding (and encoding) algorithms are used. Those algorithms perform local calculations and pass those local results via messages. The term "local calculations" already indicates that a divide and conquers strategy, which separates a complex problem into manageable sub-problems, is realized.

Furthermore, iterative decoding algorithms of sparse codes perform very close to the optimal maximum likelihood decoder.

Soft decision decoding of LDPC codes is based on the concept of belief propagation and yields better decoding performance and is therefore the preferred method. First, let's introduce some notations (Li *et al.*, 2006):

$$Pi = Pr(ci = 1|yi)$$

- q_{ij} is a message sent by the variable node c_i to the check node f_j. Every message contains always the pair $q_{ij}(0)$ and $q_{ij}(1)$ which stands for the amount of belief that y_i is a 0 or a 1
- r_{ji} is a message sent by the check node f_j to the variable node ci. Again there is a $r_{ji}(0)$ and $r_{ji}(1)$ that indicates the (current) amount of believe in that y_i is 0 or1

The step numbers in the following description correspond to the hard decision case.

All variable nodes send their q_{ij} messages. Since no other information is available at this step, $q_{ij}(1) = P_i$ and $q_{ij}(0) = 1 - P_i$

Using equation 1 and 2, the check nodes calculate their response messages r_{ji}:

$$r_{ji} = \frac{1}{2} + \frac{1}{2} \prod_{i' \in v_{j \backslash i}} \left(1 - 2q_{i'j}(1) \right) \qquad (1)$$

And:

$$r_{ji}(1) = 1 - r_{ji}(0) \qquad (2)$$

So they calculate the probability that there is an even number of 1's among the variable nodes except c_i (this is exactly what $V_{j \backslash i}$ means). This probability is equal to the probability $r_{ji}(0)$ that c_i is a 0. This step and the information used to calculate the responses are illustrated in **Fig. 5**.

The variable nodes update their response message to the check nodes. This is done according to equation 3 and 4:

$$q_{ji}(0) = K_{ij}(1 - P_i) \prod_{i' \in ci \backslash j} r_{j'i}(0) \qquad (3)$$

$$q_{ji}(1) = K_{ij} P_i \prod_{i' \in ci \backslash j} r_{j'i}(1) \qquad (4)$$

where, by the constants K_{ij} are chosen in a way to ensure that $q_{ij}(0) + q_{ij}(1) = 1$. $C_i \backslash j$ now means all check nodes except f_j. Again **Fig. 5** illustrates the calculation in this step.

The v-nodes also update their current estimation ($\hat{C}_i$) of their variable C_i. This is done by calculating the probabilities for 0 and 1 and voting for the bigger one using equations (5), (6) and (7):

$$Q_i(0) = K_i(1 - P_i) \prod_{i \in ci} r_{ji}(0) \qquad (5)$$

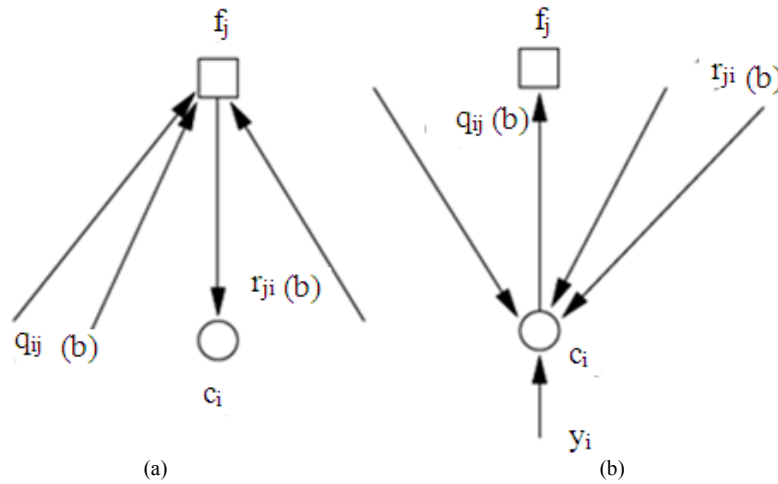**Fig. 5.** Illustrates the calculation of (a) rji(b) and (b) qij(b)

$$Q_i(1) = K_i P_i \prod_{i \in ci} r_{ji}(1) \tag{6}$$

Then:

$$\hat{C}_\tau \begin{cases} 1 \text{ if } Q_i(1) > Q_i(0) \\ 0 \text{ else} \end{cases} \tag{7}$$

If the current estimated codeword fulfills now the parity check equations the algorithm terminates. Otherwise termination is ensured through a maximum number of iterations.

Go to step 2 for more iterations.

2. MATERIALS AND METHODS

2.1. 60 GHz Technologyand Related Work

Transfer of uncompressed video signals requires larger bandwidth than that of compressed video signals.

As the signal bandwidth becomes wider, the signal processing speed at both the transmitter and receiver becomes higher, requiring about 2.5 Gsamples/s sampling rate. It is apparent that the mmWave transceiver with very short sample period is vulnerable to frequency offset, timing drift and any nonlinearity caused by the instability of 60 GHz RF components such as a Low Noise Amplifier (LNA), Voltage Controlled Oscillator (VCO) and Phase Locked Loop (PLL) (Katayama *et al*., 2007; Sarkar and Laskar, 2007) However, major challenge that makes the uncompressed HD streaming difficulty in 60 GHz frequency band is the

poor link budget. The path losses at 10 m for Line-Of-Sight (LOS) and non-LOS conditions are 88 and 92 dB, respectively, assuming an average of four dB shadowing effect (Singh *et al*., 2007). Also, the 60 GHz frequency band has oxygen absorption properties, which means that the transmitted signal is attenuated severely by oxygen molecules encountered in the transmission path. To compensate for the large path loss and obtain a reliable transmission quality, sophisticated antenna array beam forming emerges as a crucial mechanism featuring high antenna gain and adaptive steering. Therefore, maintaining good quality uncompressed HD video streaming at 60 GHz band is a very challenging task and requires further elaborations in network design.

These challenges make the 60 GHz technology not suitable in outdoor applications because of high attenuation due to path loss and humidity but suitable in indoor application i.e.,Wireless Personal Area Network (WPAN). Also some researchers are needed in electronics to overcome the problems of using high frequency components (Okada *et al*., 2011).

Standardization in 60 GHz wireless networks is currently under development by several industry consortia and international standard organizations. Wireless HD (Lawton, 2008) is an industry-led effort to define a next-generation wirelessHD interface specification for consumer electronics products. The consortium completed the WirelessHD specification version 1.0 in January 2008. European Computer Manufacturer Association (ECMA) InternationalTC48 ECMA TC32-TG20: High Rate Short Range Wireless Communication is also developing a standard for 60

GHz technology for very high data rate short range unlicensed communications to support bulk data transfer such as downloading data from a kiosk and HD multimedia streaming. In addition, IEEE 802.15 Task Group 3c (Lee *et al*., 2010) is considering an mmWave alternate physical layer for the IEEE 802.15.3-2003 standard for WPANs. While ECMA TC48 is targeting its specification completion for December 2008, IEEE 802.15.3c standardization is expected to be completed in 2009.

There has been a tremendous interest in utilizing the 60 GHz portion of the electromagnetic spectrum because of the wide bandwidth available, the propagation characteristics that allow high-density short-range links and because of the short wavelength that allows very compact antenna structures. Key to bringing 60 GHz-based products to the market place is a low cost, repeatable, mass producible means of realizing the transceiver electronics. Rappaport *et al*. (2011), they describe a chipset that they have developed which provides a high performance but cost effective solution for implementing a full band (55 to 64 GHz) transceiver suitable for a broad range of applications. The chipset has enough versatility to support various modulation schemes and can be used in simplex, duplex and full duplex mode. Through extensive compaction, the total die area for the entire chipset has been shrunk to only 17 mm^2. This small chip means a small package and the high production and high reliability process used ensures performance and yield margins.

Also since 2003, IBMhas been working on the development of 60-GHz radio transceiver Integrated Circuits (ICs) and the surrounding infrastructure to enable low-cost 60-GHz communications. In 2004, IBM demonstrated the world's first silicon-based active mixers and low-noise amplifiers at 60 and 77 GHz and also demonstrated other mm Wave radio building blocks, including power amplifiers and voltage-controlled oscillators. This work proved that it is feasible to build silicon mm Wave circuits. In early 2006, they also have demonstrated a fully integrated 60-GHz receiver and transmitter chipset, which includes all of the RF and analog portions of the radio. In addition, IBM has demonstrated low-cost packaging and antennas.

In the communication side, many researches are introduced on 60 GHz technology like Wigwam (Simon *et al*., 2007; Eberts *et al*., 2005) a project funded by the German Ministry of Research and Foundation is aiming to develop a Gigiabit system for short range communications using mm Wave band. Katayama *et al*.

(2007) IBM research presented a system level design supporting uncompressed video up to 2Gbps using SiGe radio chipsets in mmWave band (Okada *et al*., 2011). Also (Lee *et al*., 2012; Singh *et al*., 2008a; Hong and Lee, 2011; Sing *et al*., 2008) produced a new technique called pixel partitioning that we extend in this study.

2.2. Frame Partitioning Uncompressed Video for 60GHz Band using OFDM/LDPC

In a typical uncompressed video stream, geographically neighboring (spatially correlated) pixels usually have very similar or even the same values. This kind of spatial redundancy is exploited such that pixels with minimal spatial distance are partitioned into different video packets. **Figure 6** shows an example of a pixel partitioning and packetizing scheme wherein four neighboring pixels are partitioned into four video packets (Singh *et al*., 2008b). If one video packet is corrupted, one or more other packets that contain pixels spatially related to the corrupted pixel(s) can be used to recover or compensate for the corrupted pixel information.

Figure 6 complete Pixel partitioning (EEE 802.15 WPAN Millimeter Wave Alternative PHY Task Group 3c (TG3c)"; http://www.ieee802.org/15/pub/TG3c.html).

As a result, further retransmission of corrupted pixels is not required. Singh *et al*. (2008a) they present an mmWave system for supporting uncompressed HD video. This system proposed in integrates pixel partitioning, unequal error protection and error concealment.Pixel partitioning utilizes spatial redundancy by allocating adjacent video pixels in different video packets while unequal error protection and error concealment allow the receiver to recover erroneous pixels by using neighboring good pixels having higher spatial correlation.

The application layer at the video source implements pixel partitioning such that pixels with minimal spatial distance (i.e., neighboring pixels) are placed into different video packets. If a video packet transmission is corrupted, the receiver recovers the error using pixel information in other received packets containing neighboring pixels.

As a result, further retransmission of corrupted pixels is not required. The MAC layer aggregates multiple video packets into one MAC frame. Multiple CRCs are included for each aggregated payload. At the PHY layer, information bits are first scrambled to randomize the input sequence.

Then the four MSBs are parsed into the first data path and the second four LSBs are parsed into the second data path. On each data path, Reed-Solomon (RS) and convolutional codes are concatenated to protect the

information bits. The two bit streams are of different importance; the MSB bit stream carries more weight toward picture quality. Therefore, in comparison to the LSB data path, the MSB data path is strongly protected, which allows better error protection for the MSB portion of video pixels. Working with high definition uncompressed frame imposes no retransmission. In this study we do frame partitioning instead of pixel partitioning. This means that each frame is partitioned into number of sub-frames and useOrthogonal Frequency Division Multiplexing (OFDM) to protect frame from multipath fading and interference as a result of required high data rate. Also we use a Low Density Parity Check Coding (LDPC) for error detection and correction. After receiving the frame we judge on the performance of the system with two parameters, the symbol error rate and the peak signal to noise ratio. The proposed system architecture is illustrated in **Fig. 7.** It is clear in **Fig. 7** that the modulation/demodulation and LDPC encoding/decoding is applied for each sub-frame.
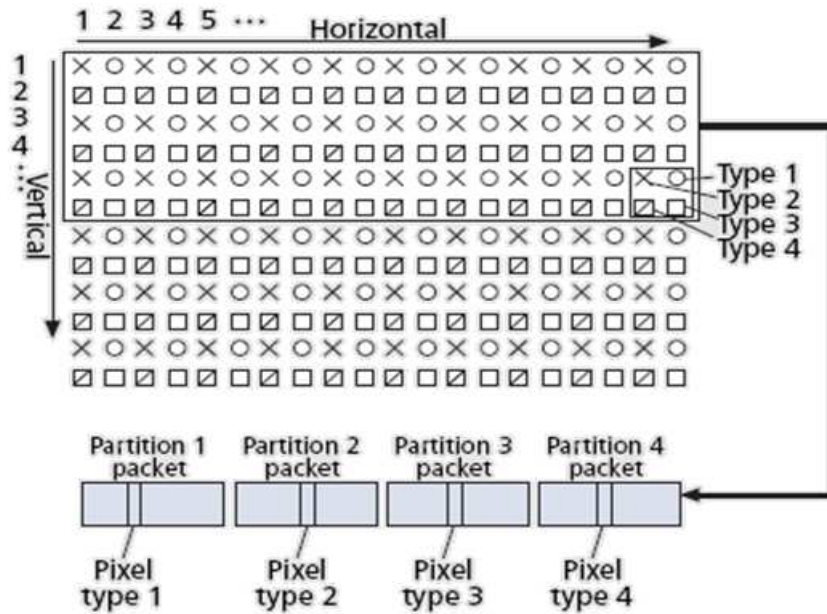

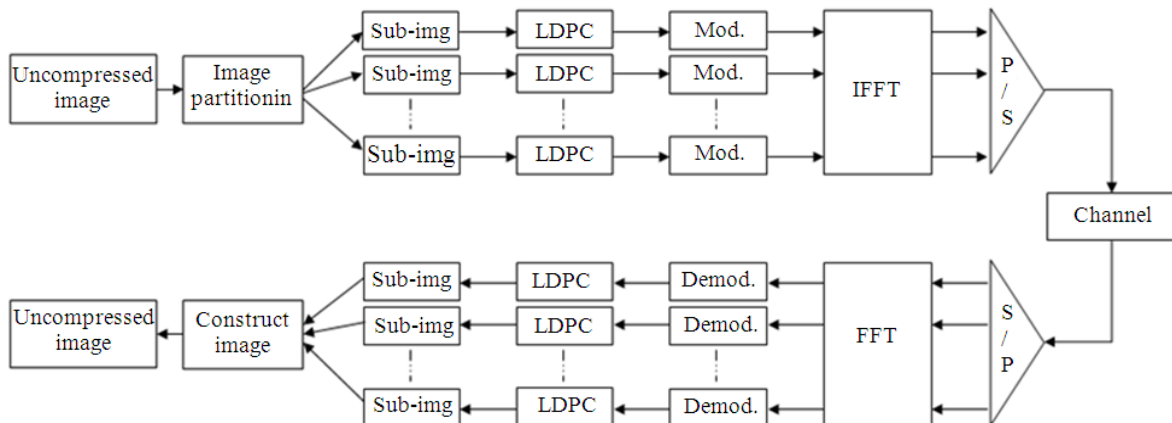**Fig. 6.** Complete Pixel partitioning (IEEE 802.15 WPAN Millimeter Wave Alternative PHY Task Group 3c (TG3c). http://www.ieee802.org/15/pub/TG3c.html)
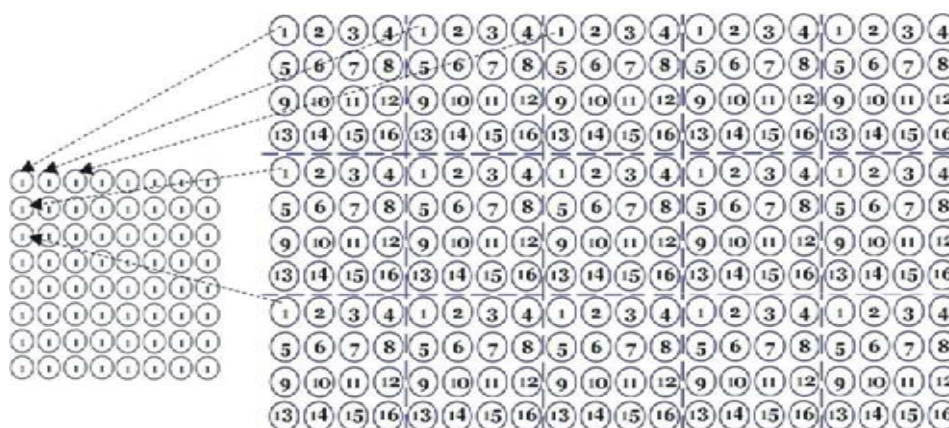

Fig. 7. System architecture

Fig. 8. (a) Sub-frame1(b) real frame

This decision was needed to utilize efficiently the concept of pixel partitioning by using the best modulation type for each sub-frame. Also different LDPC codes and rates are used. For example, we can use two types of LDPC codes with rates 3/6 and 5/12 or we can use the code rate with different generation matrix. This gives the advantage of code diversity. If we uses the same code and the same modulation technique like binary phase shift keying-BPSK- we can apply the coding and modulation before splitting the frame into number of sub-frame in one block.

As described earlier, pixel partitioning is considered kind of spatial redundancy where pixels with minimal spatial distance are partitioned into different packets. Also each pixel is divided into Most Significant Bits (MSB) and Least Significant Bits (LSB) and protects each group with unequal error protection code. This work gives a good protection technique, but also reduces the throughput because of using headers and protection codes for each pixel. In this study we introduce frame partitioning instead of pixel partitioning.

Frame partitioning stands on the concept that the neighboring pixels are highly correlated. The frame is divided into number of sub-frames. Each sub-frame contains the same information of the original frame but in smaller size and lower resolution. This study is illustrated in **Fig. 8.** First of all, we decide the number of sub-frames that will be sending over the channel. If the number of sub-frames is 16 then, get the size of the transmitted frame 424×300 and divide rows by 4 and column by 4. The result sub-frame dimension is106×75. Now we know the size of each sub-frame. Note that, it is not mandatory to divide the frame in symmetric. **Figure 8** shows the created sub-frame number 1 and other sub-frames can be created by the same way. The right hand

side frame in **Fig. 8** is illustrating the real frame, while the left hand side frame is illustrating the first sub-frame. The real frame-right hand side- is divided into groups. Each group contains 16 circles. Each circle means one pixel. The number inside each circle identifies the order of pixel in each group. Now we are ready to create the first sub-frame. Take pixel number 1 in each group and put it in a new frame with the same order of group, i.e., locate pixel number one in the first group-above left- in a new sub-frame in the first location followed by pixel number one in the successive group. By other words, for each group of pixels removes all pixels except pixels have number one and combine these pixels in the same order in a new frame called sub-frame 1. Do the same work for pixels 2, now we have sub-frame 2… Splitting the frame into a group of sub-frames is shown in **Fig. 9-10** where we can see that each sub-frame contains the same information as in real frame but with lower resolution. Deciding the number of sub-frames that may give an optimum work depends on certain parameters. These parameters depend on the frame contents and how many pixels can consider as neighboring pixels, channel conditions and more.

From the system architecture block diagram we can see that the second step in our model after splitting the frame into number of sub-frames is protecting the frame from channel noise.

Low Density Parity Check (LDPC) code is used for this error correction and protection. However, low density parity check code is not used for the original frame; it is used for each sub-frame in separate. This gives many advantages as LDPC treats each sub-frame independently and adds redundant bits to each group of pixels depending on the LDPC rate for error detection and correction.Using frame partitioning along with low density parity check code provides the following advantages.

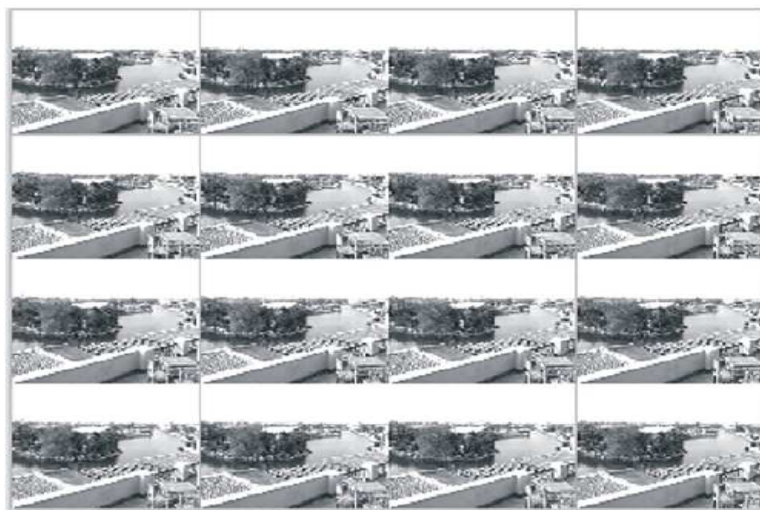**Fig. 9.** Real frame before splitting

Fig. 10. Partitioning sub-frames

LDPC is an excellent recovery code and a lot of iterations give good error recovery.

LDPC is used for each sub-frame separately and not for the whole frame. This means that the information bits multiplied with the generation matrix is not a neighboring pixels. This comes from frame partitioning step that the neighboring pixels are distributed in different sub-frames. This gives the advantage of interleaving, i.e., if the LDPC couldn't recover certain codeword, this will affect spaced pixels and these pixels can be recovered if we cancel it and put its neighboring pixels instead of the corrupted pixels.

LDPC used for protecting each sub-frame separately allows for the option of changing the rate of protection between sub-frames. Not only the rate you can change, but you can change the parity check matrix which may give you a good coding diversity for the frame.

After partition the frame into number of sub-frames and expose each sub-frame to LDPC encoder for error correction and protection from channel noise. The third step is to use the orthogonal frequency division multiplexing. The OFDM used to reduce the rate of the transmitted information to lower data rates to avoid channel noise and fading. In our work, we put each LDPC coded sub-frame on a single carrier. As the carriers are orthogonal, no interference between coded sub-frames will occurs. The OFDM signal is described in the equation 8:

$$x(n) = \sum_{k=0}^{N-1} s(k) e^{j2\pi f_k n} \quad 0 \le n \le N-1 \tag{8}$$

Where:
S(k) = LDPC code of sub-frame
N   = number of sub-carriers
Fk = Carrier frequency for subcarrier k and = k/NT
N   = Discrete time variable
T   = Sample time

When we use cyclic prefix to overcome the inter symbol interference caused by delay spread the OFDM signal is described by equation 9:

$$x(n) = \sum_{k=0}^{N-1} s(k) e^{j2\pi fk^n} \quad -CP \leq n \leq N-1 \qquad (9)$$

where, CP is Cyclic prefix.

The use of OFDM technique gives another advantage to our proposed system that each coded sub-frame will be carried on different frequency than the others. Hence, each coded sub-frame will suffer from different type of fading achieving another degree of diversity at the reception which may be helpful after receiving and decoding the frame that, not all sub-frames will see the same noise, so the correct sub-frames may be used to recover the corrupted sub-frames.

After passing the signal over noisy channel-additive white or fading channel-the receiverreceive the information and make the opposite of what we used in the transmitter side. First of all, the cyclic prefix will be removed if it was used by the OFDM at the transmitter side. After that, Fast Fourier Transform is used to return all sub-frames to base band after each was carry on different sub-carriers. LDPC decoder is used to detect and recover errors caused by the noisy channel. Finally, use the sub-frames to reconstruct the frame and view the estimated one.We test the system quality by measuring the symbol error rate caused by channel and the peak signal to noise ratio to measure how the frame noise will annoy the observer.

3. RESULTS AND DISCUSSION

One of the most important parameter that gives the quality of measurement between received frame and the original frame is the Peak Signal to Noise Ratio (PSNR). PSNR measures the peak error and higher PSNR means higher picture quality:

$$PSNR = 10 \log_{10} \left(\frac{R^2}{MSE} \right)$$

Mean Square Error (MSE) represents the cumulative squared error between the original frame and the received frame (noisy frame) and the lower MSE means lower error and higher quality:

$$MSE = \frac{\sum_{M,N} \left(l_1(m,n) - l_2(m,n) \right)^2}{M * N}$$

Where:

$M \times N$ = The dimension of the frame
I1   = The original frame
I2   = The noisy frame
R   = Maximum fluctuation in the input frame data Type
R   = 2P-1

Where:
P   = Number of bits per pixel
Ex = For binary frame (0, 1)
R   = 1 and for 8 bits for pixel
R   = 255.

Discrete simulator is used to simulate the proposed system model and four scenarios were carried out to check the efficiency of our system from communication point of view and video quality from another point of view.The four systems are described in coming sections.

3.1. Frame Partitioning Based Model

In this Scenario, we only used the frame partitioning concept and partitioned the frames into 4, 16 and 32 sub-frames. Those sub-frames are then coded and send over additive white Gaussian channel with Rayleigh fading and test the performance using symbol error rate and peak signal to noise ratio. **Figure 11** shows the block describe this system.

This scenario is very similar to the interleaving concept. If noise and/or fading is concentrated at a certain part of a sub-frame, the adjacent pixels in each sub-frame are not the neighboring pixels because the neighboring pixels are distributed in different sub-frames. After reconstruct the frame, this error will be distributed and may not annoy the observer.

3.2. OFDM Based Model

In this scenario, we add to Frame Partitioning Based Model the effect of Orthogonal Frequency Division Multiplexing (OFDM). First, we partition the frame in to 4 sub-frames. Binary phase shift keying is applied for each sub-frame elements. Carry each sub-frame on separate sub-carrier. Orthogonal carriers are used to avoid the interference. Expose the OFDM signal to the two types of noise that we are use in our simulation, the AWGN and Rayleigh noisy channels. Repeat this for 16 and 32 sub-frames and calculate the symbol error rate and PSNR. In this system each sub-frame is carried by one sub-carrier. Here, the number of sub-carriers is equal to the number of sub-frames. This means that not all sub-frames will see the same noise. The sub-frames are redundant we can consider this a type of diversity. **Figure 12** shows a block diagram describe the system.

3.3. LDPC Based Model

In this scenario, we add to Frame Partitioning Based Model the effect of low density parity check for protecting the frame from channel noise. First of all, we partition the frame into 4, 16 and 32 sub-frame. Second, we apply the LDPC encoder and expose this signal to AWGN and Rayleigh noisy channels. After receiving the signal, decode the sub-frames and calculate the symbol error rate and PSNR after reconstructing the frame again. This can be considered another type of diversity using code because the LDPC code is protecting each sub-frame and the information in the sub-frames is close to each others. We use LDPC code with rate (3,6), i.e., three redundant bits are added for each 3 information bits. The same LDPC code is applied to each sub-frame.

Note that, different LDPC code rate can be used for some sub-frames. Also the same rate can be used with different parity check matrix applied for each sub-frame, but in our work, we use the same LDPC parity check matrix and same rate for all sub-frames. **Figure 13** shows system architecture.

3.4. OFDM/LDPC Based Model

In this scenario we partition the frame, use LDPC protection code for each sub-frame and send each encoded sub-frame on different sub-carrier. **Figure 7** describes the system architecture. First, we partition the frame into 4 sub-frames. Encode each sub-frame with low density parity check code-same code- for error protection. After encoding, each encoded sub-frame is carried by different sub-carrier. Multiplex all sub-frames and put it in series form. Send the signal over Additive White Gaussian Noise and Rayleigh noisy channels. At the receiver side, de-multiplex the sub-frames, return all sub-frames to the base band decode. Each sub-frame in separate and correct the errors and finally reconstruct the frame from the received sub-frames. Test the system performance using the two parameters: symbol error rate and peak signal to noise ratio. Repeat these steps for different number of sub-carriers 4, 16 and 32. Note that, sub-carriers carry different sub-frames. Hence when we use 16 sub-carriers we also split the frame into 16 sub-frames and the same for 32 sub-carriers. A flow chart in **Fig. 14** illustrates the sequence of our process algorithm.

3.5. Simulation over Awgn Noisy Channel

The results-symbol error rate and peak signal to noise ratio-for the four systems after the simulation over AWGN at different signal to noise ratio levels varying from 0 to 10dB is shown on **Fig. 15a-b**. We called Frame partitioning model by frame only, OFDM based model by OFDM, LDPC based model by LDPC and OFDM/LDPC based model-combined system-by complete system while **Fig. 16** shows the received picture at the four systems at 3dB.

These figures show that there are no significant contributions to using the whole proposed system compared to the system only implementing LDPC. Also the figures show that OFDM does not contribute to the enhancement of the performance of the system.
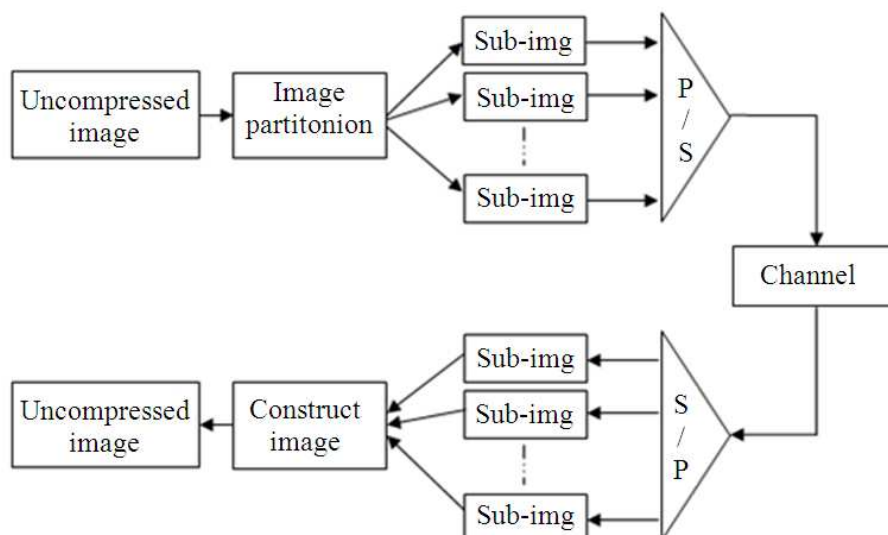
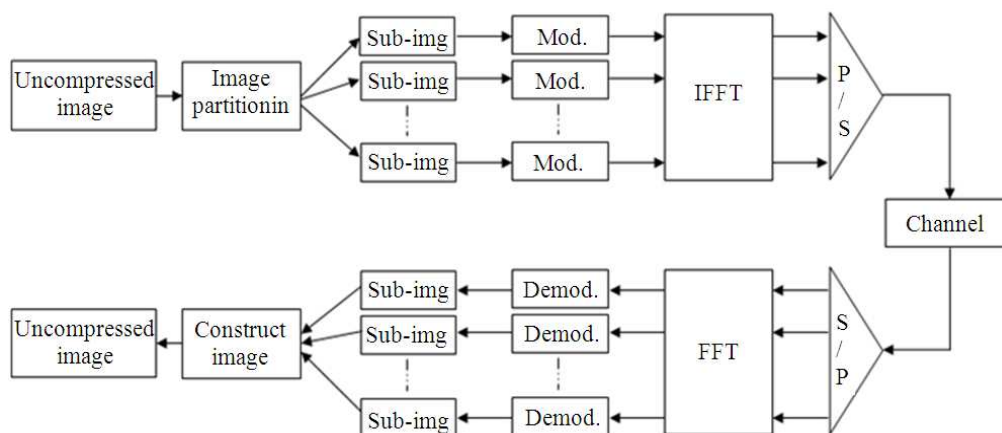

Fig. 11. Frame portioning based model architecture

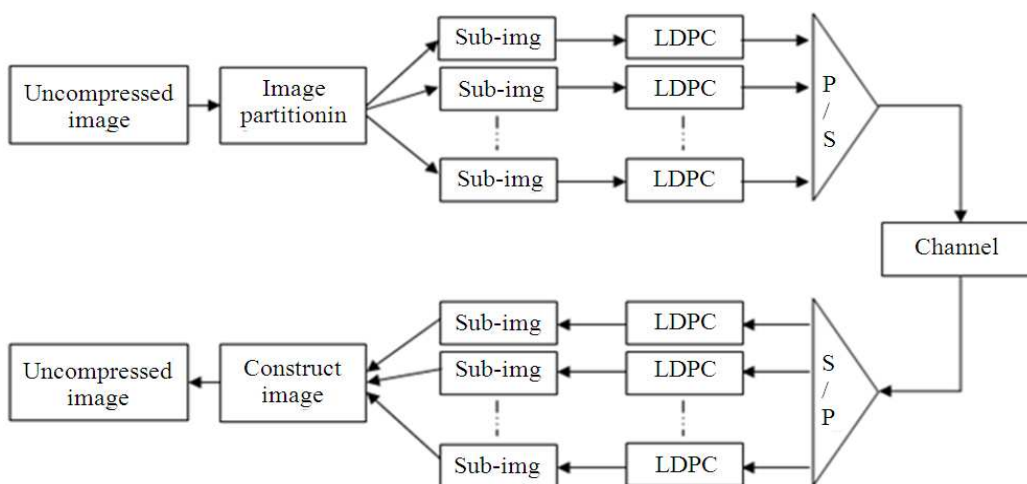**Fig. 12.** OFDM based model architecture

Fig. 13. LDPC based model architecture

This is reasonable as it is well known that it is useless to use OFDM over the AWGN channel as it has no effect on the symbol error rate or on the peak signal to noise ratio, while, we can sense the valuable effect of LDPC. LDPC code protects the frame from channel noise and recovers bad pixels and this can noticed from the lower symbol error rate and the incensement on PSNR.

3.6. Simulation over Rayleigh Noisy Channel

The results-symbol error rate and peak signal to noise ratio- for the four systems after the simulation over Rayleigh noisy channel at different signal to noise ratio levels varying from 0 to 10 dB at 4 sub-frames and 4 sub-carriers are shown on **Fig. 17a-b**). **Figure 18** shows the received frames at the four systems at 9dB.

From these figures, we can see the superiority of our proposed system compared to the three other systems. The worst performance is that of the only using frame partitioning followed by LDPC then OFDM. An enhancement of almost 2 dB in symbol error when using our system compared to using only frame partitioning. From the visual quality of the frames, we can also notice from **Fig. 18** that our system has the clearest visual quality.

Figure 18 received frames at 9 dB resulted from using 4 sub-frames passed over Rayleigh channel on system (a) frame partitioning based model (top left) (b) OFDM based model (top right) (c) LDPC based model (bottom left) (d) combined system (bottom right)
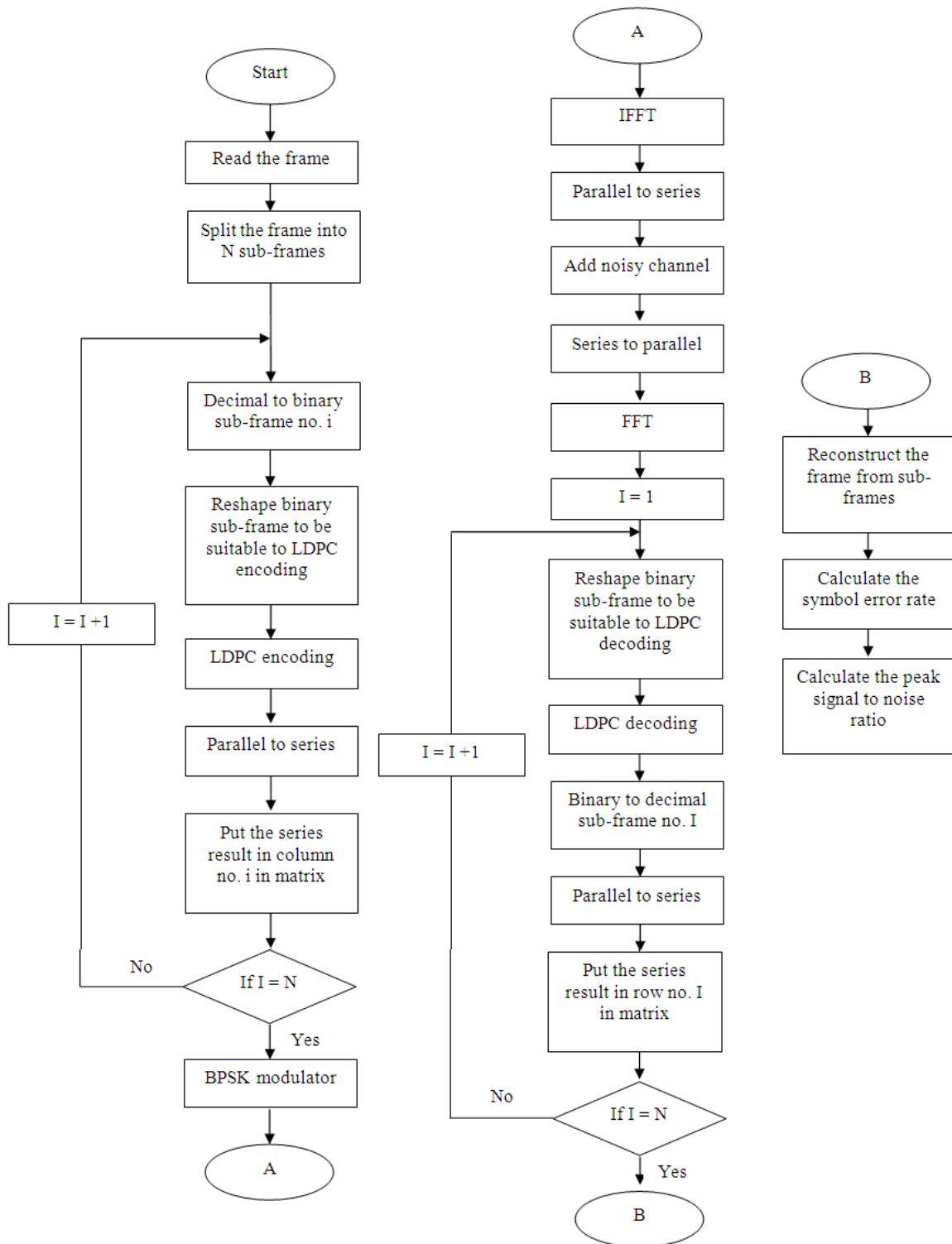
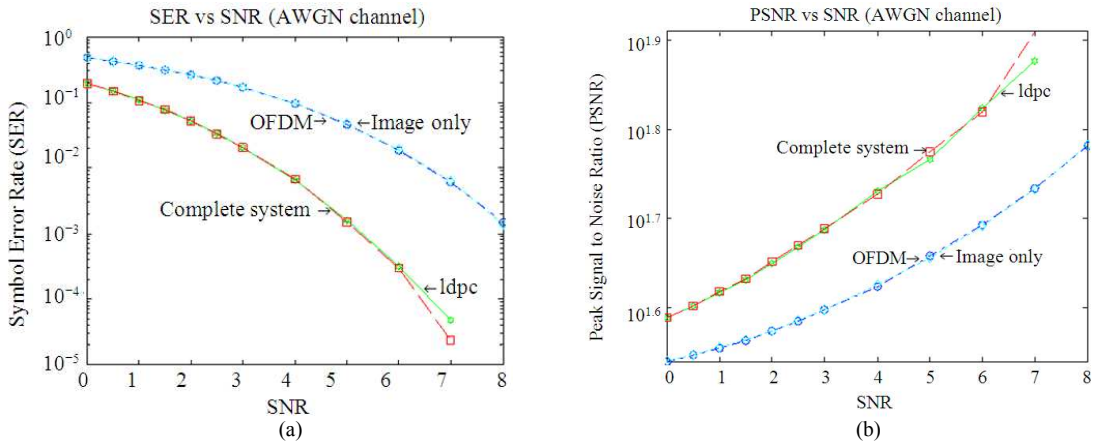**Fig. 14.** MATLAB program flow chart

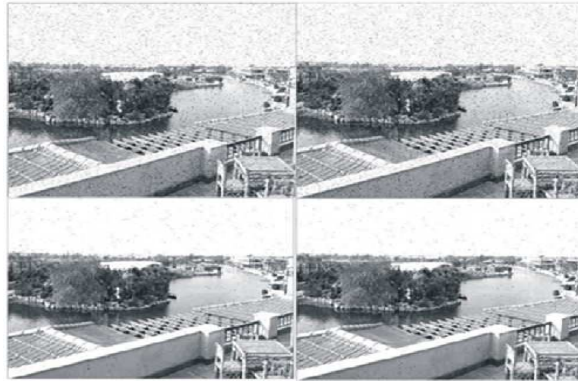**Fig. 15.** (a) Symbol error rate over AWGN (b) PSNR over WGN

Fig. 16. Received Frames at 3 dB resulted from using (a) frame partitioning based model (top left) (b) OFDM based model (c) LDPC based model (bottom left) (d) combined system (bottom right) over AWGN channel
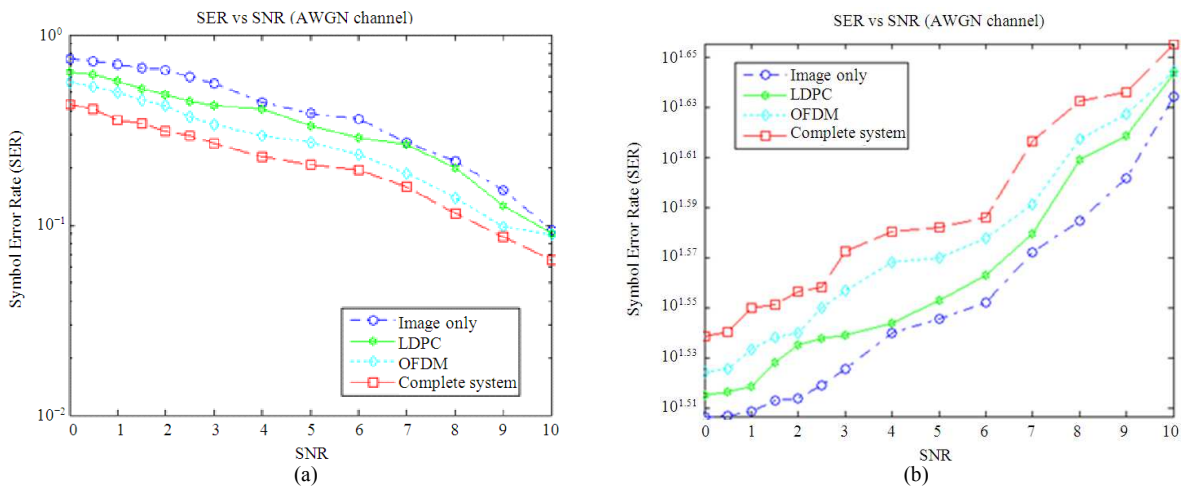

Fig. 17. (a) Symbol error rate at 4sub-carriers (b) PSNR at 4 sub-carriers
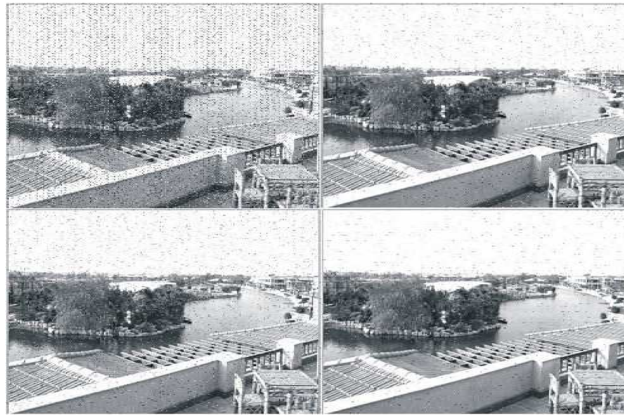
Fig. 18. Received frames at 9 dB resulted from using 4 sub-frames passed over Rayleigh channel on system (a) frame partitioning based model (top left) (b) OFDM based model (top right) (c) LDPC based model (bottom left) (d) combined system (bottom right)
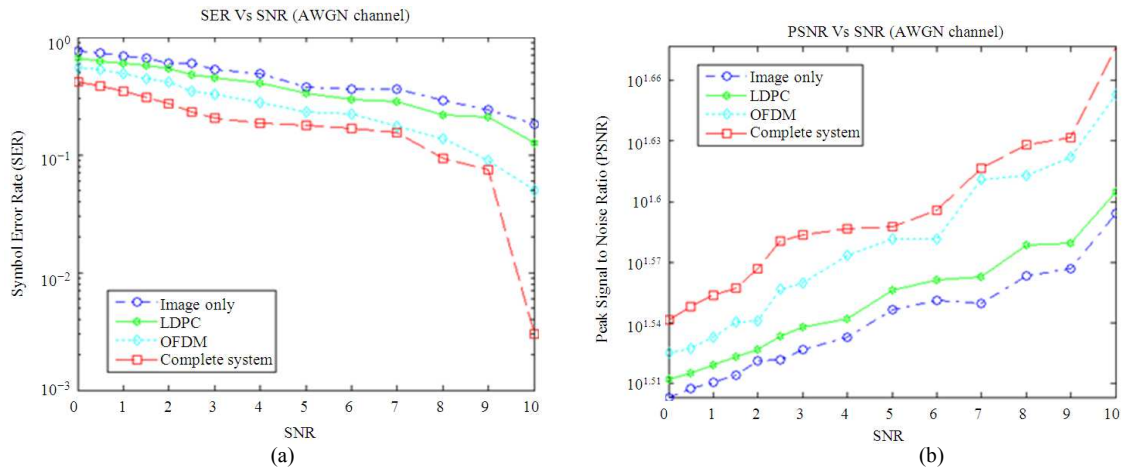

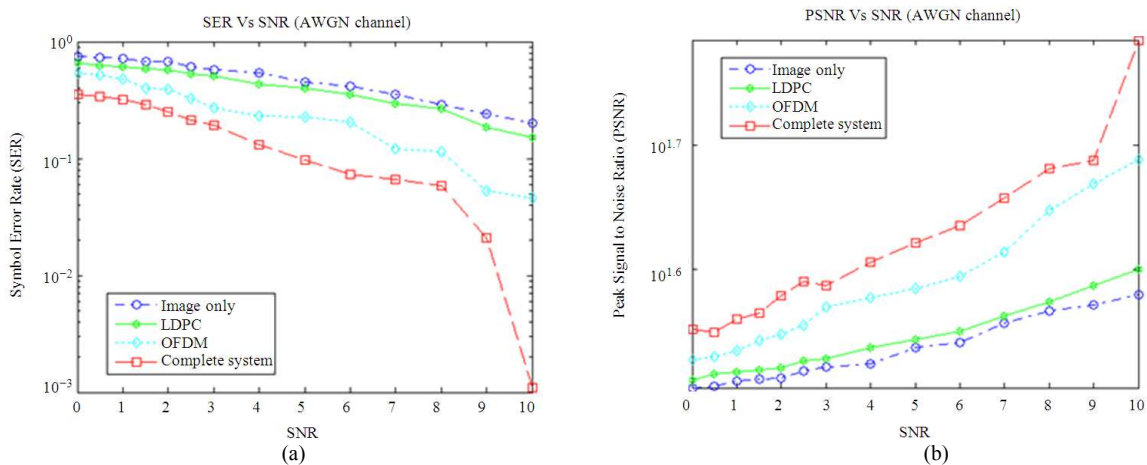**Fig. 19.** (a) symbol error rate at 16 sub-carriers (b) PSNR at 16 sub-carriers

Fig. 20. (a) Symbol error rate at 32 sub-carriers (b) PSNR at 32 sub-carriers
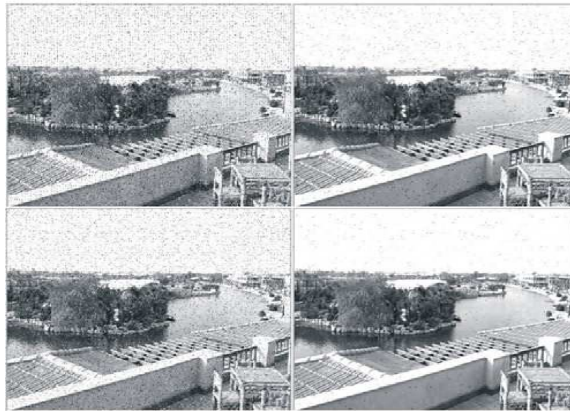
Fig. 21. Received pictures at 9 dB resulted from using 16 sub-frames passed over Rayleigh channel on system (a) frame partitioning based model (top left) (b) OFDM based model (top right) (c) LDPC based model (bottom left) (d) combined system (bottom right)

Fig. 22. Received pictures at 9 dB resulted from using 32 sub-frames passed over Rayleigh channel on system (a) frame partitioning based model (top left) (b) OFDM based model (top right) (c) LDPC based model (bottom left) (d) combined system (bottom right)
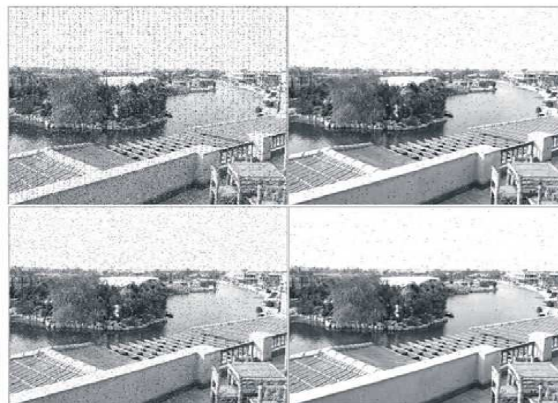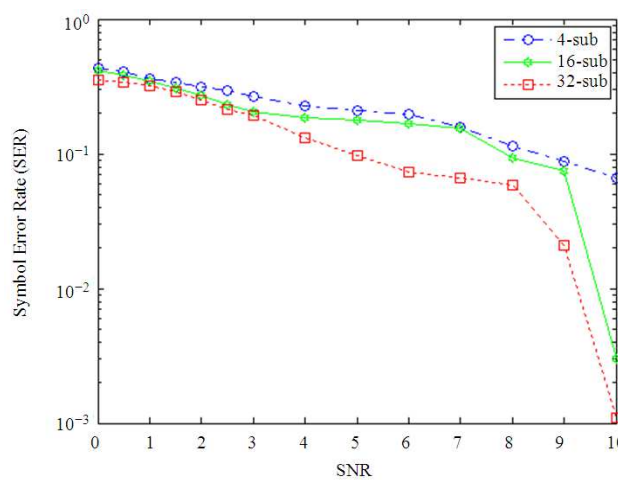

Fig. 23. Symbol error rate at 4, 16 and 32 sub-carriers when using system IV

We re-run the simulation for 16 and 32 sub-frames and sub-carrier in Rayleigh fading channels. **Figure 19 and 20** shows the symbol error rate and SNR when using 16 and 32 sub-frames respectively.

Also **Fig. 21 and 22** shows the received pictures at the four systems at 9 dB when using 16 and 32 sub-frames respectively.

Figure 23 shows the symbol error rate at 9 dB for system IV when using 4, 16 and 32 sub-carriers. This shows us that increasing the sub-carrier enhances the symbol error rate even at low SNR.

4. CONCLUSION

In this study we illustrated the concept of frame partitioning that can be used to split the frame into sub-frames to make each sub-frame suffer from different type of noise and satisfy the special diversity. We have discussed the LDPC encoding/decoding that is used for error detection and correction which can improve the system performance and reduce the received corrupted pixels. We simulate a system that uses LDPC over both AWGN and Rayleigh channel and check its ability to reduce errors. Simulation also for OFDM and Hybrid system is done over AWGN and Rayleigh noisy channels. The simulations are repeated for different number of sub-carriers. From simulation over AWGN, we test the effect of OFDM with different type of sub-carrier and found that it has no effect on improving the system performance or picture quality. After simulating the system that uses LDPC for error detection and correction we found it improves the system performance. Also the hybrid system that uses both LDPC and OFDM together didn't give better performance than using the system that uses LDPC only. But from Rayleigh channel, we found that OFDM has a good effect on the frame quality. In addition, increasing number of sub-carriers gives a better performance. Using LDPC gives better performance than sending the picture without protection. Hybrid system that uses both LDPC and OFDM together takes the advantage of both techniques and gives the better performance than using each technique in separate. Also, changing the number of sub-carriers in OFDM system and in the hybrid system gives a better performance than lower number of sub-carriers.

In future work, we can change the modulation technique by working with higher order modulation techniques along with adaptive modulation and coding for each sub-frame. In addition, we can change the LDPC generation matrix without changing its rate by applying different LDPC error detection and correction code to each sub-frame.

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