Energy Efficient Image Transmission with Security in Wireless Sensor Networks

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Abstract **—A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure etc. and to cooperatively pass their data through the network to a main location. Transmission of large sized images can be a bottleneck for a Wireless Multimedia Sensor Nodes due to its limited resources. Energy of the individual sensor and Security is also a major constraint in Wireless Multimedia Sensor Networks. In the proposed system the problem of security is overcome by sending the sensitive data through multiple node disjoint-paths so that it is impossible for an adversary to get the entire information by compromising a single path. The Images are transmitted within a low energy budget over the Wireless Sensor Networks by using unequal error protection. In addition, acknowledgements are used, to recover from the loss of image fractions and retransmitting it through an alternate path.**

***Keywords*-Wireless Sensor Networks, Network Security, Correlation, Unequal Error Protection, Image Quality.**

I. Introduction

A Wireless sensor network consists of sensor nodes that are powered by small irreplaceable batteries. These sensor nodes are densely deployed in the area to be monitored and sense and transmit data towards the base station. A sensor network can be both standard data sensors and video sensors. With the availability of low-cost small imaging sensors (mostly implemented by CMOS cameras), which may ubiquitously capture multimedia content, wireless image sensor networks have been proposed to support diverse multimedia applications such as multimedia surveillance networks, target tracking, environmental monitoring, and traffic management systems. These applications require energy-efficient multimedia processing and may need image sensor array to conduct collaborative image transmissions under limited resource constraints. However, image sensors generate a large amount of data traffic in a WSN, which may become the bottleneck of network. The image data transmissions in WSNs can drastically degrade the network performance and sensor lifetime [1]-[2].

In this paper we have considered a heterogeneous cluster based wireless image sensor network architecture because it has advantages over homogeneous networks in image processing and transmission. In homogeneous networks all the sensor nodes are identical in terms of battery energy and hardware complexity. In a heterogeneous sensor network, two or more different types of nodes with different battery energy and functionality are used. The motivation being that the more complex hardware and the extra battery energy can be embedded in few cluster head nodes, thereby reducing the hardware cost of the rest of the network. However fixing the cluster head nodes means that role rotation is no longer possible. Clustered sensor networks could also be classifed as single hop and multi-hop. A single hop network is one in which sensor nodes use single hopping to reach the cluster head. In multi-hop, network nodes use multi-hopping to reach the cluster head. In both cases, the cluster heads use single hopping to reach the base station, since we assume a remote base station.

In the literature [3] the limitation of key based security management is removed. In the key based security management, if the decryption key is lost or corrupted during transmission it is difficult to recover the information. Especially, encrypting large size image data might suffer high computation complexity and latency. The secret information cannot be recovered if the decryption key is lost or the encrypted content is corrupted during transmission.

The security in transmission is thus achieved by sending the overlapped images through multiple paths calculated. First we propose , transmission of overlapped region with unequal error protection through multiple node disjoint paths. Second, the quality of the image and the security problems are resolved.

The rest of the paper is organized as follows. Section II describes the background and related works. In section III we have exploited the methods to find the overlapped images through correlation coefficient and have used the Unequal Error Protection scheme to transmit the image with minimal energy. In Section IV, we have discussed about the transmission of overlapped images through multiple node disjoint paths so that it is difficult for the adversary to compromise the sensitive information. The simulation results are demonstrated in

Section V. Finally the conclusions are drawn in Section VI.

II. Related Works

Previous researches have been reported in the literature regarding the energy efficiency by using various algorithms and protocols. In [4], the optimization of energy efficient protocols is discussed with the sleep and wakeup strategies in solar-powered wireless sensor networks under quality-of-service (QoS) constraints. Our previous work [5]-[6] exploited multiple route paths with consideration of rate adaptation, adaptive modulation and coding (AMC), and power control (PC) techniques based on channel state information (CSI) and residual energy information (REI). These multiple route paths offer path diversities and protect image transmission. The research carried out in [7]-[9] proposed a joint source channel coding approach for energy efficient JPEG2000 image transmission in WSNs, by applying different error resilient coding protection to different levels or layers of bit streams.

Researches carried out in [10] and [11] investigated the tradeoff between energy consumption and image quality.

In [12], Li proposed a retry limit adaptation scheme to achieve UEP for layer-coded video streaming over 802.11 based Wireless Local Area Networks (WLANs), where the video layers were protected over the wireless link with different ARQ retry limits. In [13] Wu proposed a scalable JSCC scheme to achieve optimized overall distortion reduction for multiple reconstructed images. In that approach, the layered distortion expectation was modeled and a quality scalable image coder was used to optimally allocate bit budget among all sources.

In [14] , Enyan Sun, Xuanjing Shena,Haipeng Chen has proposed a low energy image compression algorithm, where image quality of an interested area is discussed and compression ratio of whole image is increased. This prolongs the network life time. In this algorithm image is divided into region of interest(ROI) and tiles. This algorithm is suitable for single path transmission. In [15], Pinar Sarisaray Boluk · Sebnem Baydere · A. Emre Harmanci proposed a robust image transmission over wireless sensor network. ECMF and ECDP algorithms are capable of restoring corrupted images in WSN, especially for bursty channel error conditions and instant node failures. These schemes give significantly superior performance than all other schemes including RS. In [16], Huaming Wu, Alhussein A. Abouzeid, proposed a scheme where node rotation is used to prolong the network lifetime. In [17], Zhen Zuo, Qin Lu , Wusheng Luo proposed a scheme,where the camera-equipped node acts as a cluster head and forms its own camera cluster. By adjusting the transmission radius of the camera equipped node and allocating the image compression tasks based on the unequal residual energy distribution of the sensor nodes, the network lifetime is maximized.

III. Correlation Coefficient And Unequal Error Protection

A. Correlation Coefficient

Local image matching (block-matching) is a frequent operation in many image processing tasks, such as MPEG compression and the estimation of optical flow and stereo disparities. Normalized cross-correlation (NCC) [18] is particularly useful since it is insensitive to both signal strength and level.

Normalized cross correlation (NCC) [18] has been commonly used as a metric to evaluate the degree of similarity (or dissimilarity) between two compared images. The main advantage of the normalized cross correlation over the cross correlation is that it is less sensitive to linear changes in the amplitude of illumination in the two compared images. Furthermore, the NCC is confined in the range between –1 and 1. The setting of detection threshold value is much easier than the cross correlation. Correlation-based methods have been used extensively for many applications such as object recognition, face detection motion analysis and industrial inspections of printed-circuit boards, surface-mounted devices, wafers, printed characters, fabrics, ceramic tiles, etc. In this paper, we use a fast normalized cross correlation method to find the overlapped image.

In object recognition or pattern matching applications, one finds an instance of a small reference template in a large scene image by sliding the template window in a pixel-by-pixel basis, and computing the normalized correlation between them. The maximum values or peaks of the computed correlation values indicate the matches between a template and sub images in the scene.

Typically block-matching [11] is done by comparing a block with a number of blocks within a region in another image. The block in the search region with the highest correspondence value is selected as the matching block. There are several ways to measure the correspondence between two blocks. Cross-correlation gives a robust and dense measure of the correspondence between two blocks. In particular if you normalize the cross-correlation in terms of mean and variance you will get a correspondence measure that is insensitive to luminance scale and level. Burt et al showed in a comparison that the normalized cross-correlation consistently gave the lowest error rates compared to non- or partially normalized Laplacian filter. Block-matching requires extensive computations and there exists several algorithms to speed it up, e.g. by reducing the number of blocks to compare with by using different search strategies, and by using pyramid representations and do the search in a coarse-to-fine way.

In this paper, we consider a heterogeneous cluster based network where each node sends the information to the cluster head, which process and sends the image to the base station through single hop. The images captured by the sensor nodes may overlap with each other. When all the nodes send the overlapped region to the base station it causes traffic in the network and involves more processing which reduces energy of each sensor nodes. Therefore it is necessary to separate the overlapped and non-overlapped regions. The overlapped regions has to be transmitted with more security than the non-overlapped regions. The overlapped regions are found out using the correlation coefficient. A measure that determines the degree to which two variable's movements is associated.

B. Unequal Error Protection

In many communication scenarios, such as wireless networks, interactive systems, and control applications, where sufficient error protection becomes a luxury, providing such a uniform protection for all the information may be either a wasteful or an infeasible approach. Instead, it is more efficient here to protect a (crucial) part of information better than the rest. For example, In a wireless network, control signals including channel state, power control, and scheduling information are often more important than the payload data, and should be protected more carefully. Thus even though the final objective is delivering the payload data, the physical layer should provide a better protection to such protocol information. Similarly for the Internet, packet headers are more important for delivering the packet and need better protection to ensure that the actual data gets through. Another example is when a multiple resolution source code is transmitted over a wireless channel. The coarse resolution needs a better protection than the fine resolution because then user can at least have some crude reconstruction after bad channel realizations. These examples demonstrate the heterogeneous nature of information in contrast with the classical homogeneous view. For these situations, unequal error protection (UEP) is a natural generalization to the conventional content-blind information processing. The simplest method of unequal error protection is to allocate different channels for different types of data. For example, wireless systems allocate a separate "control channel", often with short codes and low spectral efficiency, to transmit control signals with high reliability.

In the existing formulations of unequal error protection codes, the information bits are divided into subsets, and the decoding errors in different subsets of bits are viewed as different kinds of errors. For example, one might want to provide a better protection to one subset of bits by ensuring that errors in these bits are less probable than the other bits. We call such problems "bit-wise UEP".

However, in some situations, instead of bits one might want to provide a better protection to a subset of messages. For example, one might consider embedding a special message in a normal k-bit code, i.e., transmitting one of $2^k + 1$ messages, where the extra message has a special meaning and requires a smaller error probability. Note that the error event for the special message is not associated to error in any particular bit. Instead, it corresponds to a particular bit sequence being decoded as some other bit sequence. In this paper we apply bit-wise UEP.

We apply wavelet transform to compress the overlapped images. The transform of a signal is just another form of representing the signal. It does not change the information content present in the signal. The Wavelet Transform provides a time-frequency representation of the signal.

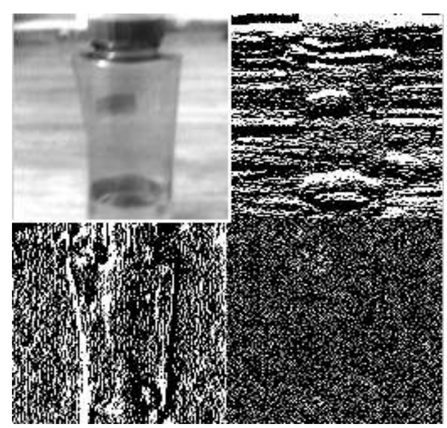

Fig .1. Illustration of single-level 2-D wavelet decomposition

Fig. 1 illustrates the single-level 2-D wavelet decomposition of an image taken for study. The top-left block is the result of approximation coefficient matrix

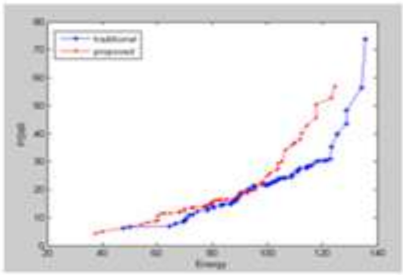

Fig 2.PSNR Vs Energy

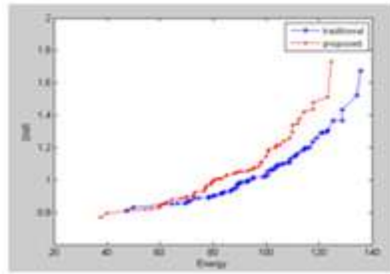

Fig 3. SNR Vs Energy

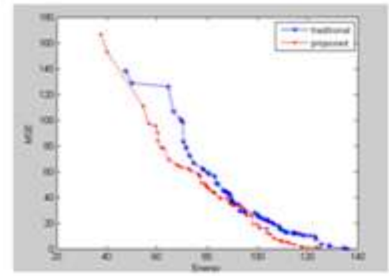

Fig 4. MSE Vs Energy

for the given image. The top-right, bottom-left and bottom-right is the result of horizontal, vertical and diagonal coefficient matrix respectively.

IV. TRANSMISSION THROUGH MULTIPLE NODE DISJOINT PATHS

With the transmission diversity for different image regions on multiple paths, our goal is to find an optimal solution to achieve higher energy efficiency and better network lifetime.

In this paper, we consider images from four sensor nodes for convenience. These sensor nodes sends the captured images to the cluster head which processes the images to find the correlation coefficient. The one with maximum correlation coefficient is selected for transmission. The image is then divided into various blocks. The UEP scheme is applied to each block of the selected image in order to send the image with a low energy budget. This saves the lifetime of the network which is a major problem in wireless sensor networks. Each block is allocated to different channels so that, the adversary cannot get the information by just compromising a single path. They have to compromise atleast half the number of channels in order to guess the information. In our proposed system we are using the Rayleigh fading channel in order to send the information through different paths. The phase of each path can change by 2π radian when the delay $\tau_n(t)$ changes by $1/f_c$. If f_c is large, relative small motions in the medium can cause change of 2π radians. Since the distance between the devices are much larger than the wavelength of the carrier frequency, it is reasonable to assume that the phase is uniformly distributed between 0 and 2π radians and the phases of each path are independent. When there are large numbers of paths, applying Central Limit Theorem, each path can be modelled as circularly symmetric complex Gaussian random variable with time as the variable. This model is called Rayleigh fading channel model**.** Rayleigh fading channel model is reasonable for an environment where there are large numbers of reflectors.

In order to ensure quality of the image received, we find the signal-to-noise ratio of different blocks and set up a threshold so that the blocks whose SNR is below the threshold is considered as of low quality and it is retransmitted through different paths.

V. SIMULATION AND ANALYSIS

In this section, we aim to find the overlapped images to be transmitted to the base station with low energy using the correlation coefficient. In the existing system images are transmitted through multiple paths. We have proposed a system which uses UEP in order to reduce the energy of transmission. Matlab 2010 is used for the implementation.

Fig 4. shows the variation of PSNR and Energy consumption for various blocks. Peak Signal-to-Noise Ratio, the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. PSNR is usually expressed in terms of the logarithmic decibel scale. The signal in this case is the original data, and the noise is the error introduced by compression. A higher PSNR generally indicates that the reconstruction is of higher quality, in some cases the reverse may be true.

PSNR is calculated using the following formula:

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

$$= 20.\log_{10}\left(\frac{MAX_I}{\sqrt{MSE}}\right) \quad (1)$$

$$= 20.\log_{10}(MAX_I) - 10.\log_{10}(MSE)$$

Where, MAX_I is the maximum possible pixel value of the image.

As shown in the fig.2 in the proposed system the PSNR value of a particular block is found to be higher than the existing system with minimal energy consumption. Fig 3. shows the variation of SNR and Energy consumption for various blocks. Signal-to-noise ratio is a measure that compares the level of a desired signal to the level of background noise.

While SNR is commonly quoted for electrical signals, it can be applied to any form of signal. The SNR is defined as

$$SNR_{db} = 10.\log_{10}\left(\frac{P_{signal}}{P_{noise}}\right) = P_{signal,\,db} - P_{noise,\,db} \quad (2)$$

As shown in the fig.3 in the proposed system the SNR value of a particular block is found to be higher than the existing system with minimal energy consumption.

Fig 4. shows the variation of MSE and Energy consumption for various blocks. PSNR is most easily defined via the mean squared error(*MSE*). Given a noise-free $m \times n$ monochrome image I and its noisy approximation K, *MSE* is defined as:

$$MSE = \frac{1}{m\,n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)] \quad (3)$$

As shown in the fig.6 in the proposed system the MSE value of a particular block is found to be lower than the existing system with minimal energy consumption. Thus from the above graphs it is clear that the proposed system is energy efficient and secure than the existing one.

VI. Conclusion

In this paper, we have studied the way in which each correlated image sensor within a Wireless Sensor Network can transmit the overlapped region to the cluster head optimally and the methods in which the overlapped images can be sent through multiple paths. In addition, we have used the Unequal Error Protection to send the images within a less energy budget. Here the quality of the image is achieved by retransmitting the low quality blocks through different paths. This approach achieves considerable gains with respect to the energy efficiency, security and network lifetime in an image-sensor based Wireless Sensor Networks. The simulation result of PSNR Vs Energy consumption graph shows that our system considerably transmits good quality images when compared to the existing system.

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