International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 3, Issue 6, June 2014

Image Fusion forWireless Sensor Networks

B.Roopa
Dept. of Electronics and Communication Engineering
REVA Institute of Technology and Management
Bengaluru, India

Sunilkumar.S.Manvi
Dept. of Electronics and Communication Engineering
REVAInstitute of Technology and Management
Bengaluru, India

***Abstract*—Major source of energy consumption in Wireless Sensor Networks (WSNs)is transmission of image from source to sink and image processing at the nodes. The captured image at the source could be noisy, incomplete and redundant. Fused image free of redundancy, brings out complementary features and aids in further analysis. This paper is on fusion of images from a set of neighbor nodes which we call as source group. Fusion algorithms take certain time for fusing the images and it differs from algorithm to algorithm. Fusion time adds to latency and influences the energy consumption at the nodes in WSN. We have evaluated image fusion in MATLAB using averaging, select maximum, PCA, DCT, DWT, SWT in terms fusion evaluation metrics, energy, computational time aspects for WSN. From these results we conclude that smart trade-off between fused image quality, latency and energy consumption depending on the application can prolong the WSN lifetime**

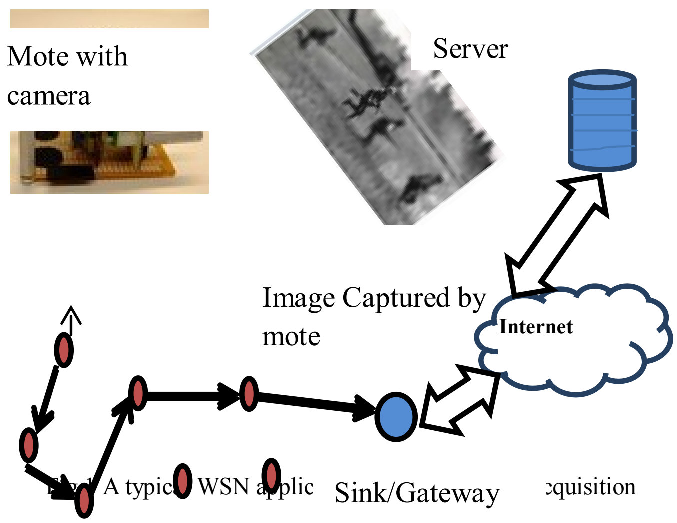
Keywords-- WSN, image fusion, DCT, DWT

I. INTRODUCTION

Internet of things (IoT) is the buzzword that is awaited to do the real magic to the human kind. WSNs indeed would be integral part of IoT. WSNs have plenty of applications like temperature sensing, landslide detection, automated parking, medical diagnosis, machine maintenance, disaster management etc [1]..A typical WSN application involving image transmission is shown in Fig.1 WSN with vision (camera equipped nodes) along with many more integrated sensors like microphones form the class of Wireless Multimedia Sensor Networks (WMSN). WMSNs have unfolded new class of applications like intruder detection, surveillance etc [2].

WSNs face energy, bandwidth, memory, computational crisis because of the demanding applications which force them trade-off many sophistications. Imagefusion has proven to be an indispensable tool for remote sensing and medical imaging. In the recent years image transmission in WSN was a challenging task, and many authors have done good deal of work to transmit image using compression. But along with compression we can combine fusion since processing power of nodes is ample enough in the recent WSN technology. In this paper we discuss the effect of choosing the particular fusion algorithm on latency and energy consumptions.

The rest of the paper is organized as follows. Section II gives briefs out the related work done in image fusion and image processing in WSN.Section III covers implementation of the algorithms. Section IV gives the account of WSN and image fusion evaluation parameters along with network model considered. Section V is the simulation results and discussion followed by conclusion and scope for future work in section VI.



A typic WSN applic cquisition

II. RELATED WORK

Though we don't find exclusive literature on image fusion techniques in WSN, there have been works on energy efficient image transmission which involve compression and image fusion. Manvi et al,. [7], proposed a Context Aware agent based Distributed Sensor Network (CADSN) to form an improved infrastructure for multi-sensor image fusion to monitor the militant activities. The proposed work is based on context aware computing which uses software mobile agents for image fusion in WMSN. Instead of each source node sending sensed images to the sink node, images from the different active nodes are fused using DWT and sent to sink node by using mobile agent. MinWu et al, used a shape matching method based image fusion [8] assuming that

ISSN: 2278 – 909X

background is not going to change over the desired interval. In that proposed work background is transmitted only once to the sink and later on only the changes are encoded and sent to sink. In the sink the background and change received is fused. What kind of fusion technique is used is not stated.Nasri,etal[9] have adopted distributed image compression taking advantage of JPEG 2000 still image compression which optimizes network life time and memory requirements but not considered fusion aspect. Image fusion is popular in image processing since many years and we can find exclusive literaturein [3],[4],[5],[6].

III. THE IMAGE FUSION ALGORITHMS

Image fusion is the process of combining the information from two or more image data into a single integrated useful image. It is assumed that images are compressed before transmission and decompressed before fusion. It is also assumed that images are registered and each of the selected nodes has images ready to be fused. Let imag1, imag2 to be the test images to be fused and fused_imag is the fused image.

A. Averaging and Select Maximum

Averaging technique is an elementary method wherein we compute average of two images at pixel level given by

fused_imag (i, j) =(imag1(i, j)+imag2(i, j))/2

However it yields reduced contrast but can be useful in WSN in certain occasions like to supplement the detection of metal gun by metal detectors.

Select maximum too is a very old fusion method wherein we compute fusion by selecting the maximum value of two images at pixel level given by

fused_imag(i,j) =max(imag1(I, j)+imag2(I, j))

B. Discrete Cosine Transform

The transformed array obtained through DCT is also of the size N x N, same as that of the original image block. DCT can be used for fusion as described below [13].

1. Decompose source images into sub- blocks
2. Apply 2D-DCT for each sub-block
3. Calculate normalized transform coefficients
4. Mean value of 8*8 block of images
5. Choose the sub-block which has high value of mean
6. For all these sub-blocks compute 2D-IDCT to get fused image[12].

C. Principal Component Analysis

The PCA is used extensively inimage compression and image classification. The PCAinvolves a mathematical procedure that transforms anumber of correlated variables into a number ofuncorrelated variables called principal components. Itcomputes a compact and optimal description of the data set.The first principal component accounts for as much of thevariance in the data as possible and each succeedingcomponent accounts for as much of the remaining varianceas possible. First principal component is taken to be alongthe direction with the maximum variance. The secondprincipal component is constrained to lie in the subspaceperpendicular of the first. Within this Subspace, thiscomponent points the direction of maximum variance. Thethird principal component is taken in the maximumvariance direction in the subspace perpendicular to the firsttwo and so on as depicted in the Fig.2.[5].

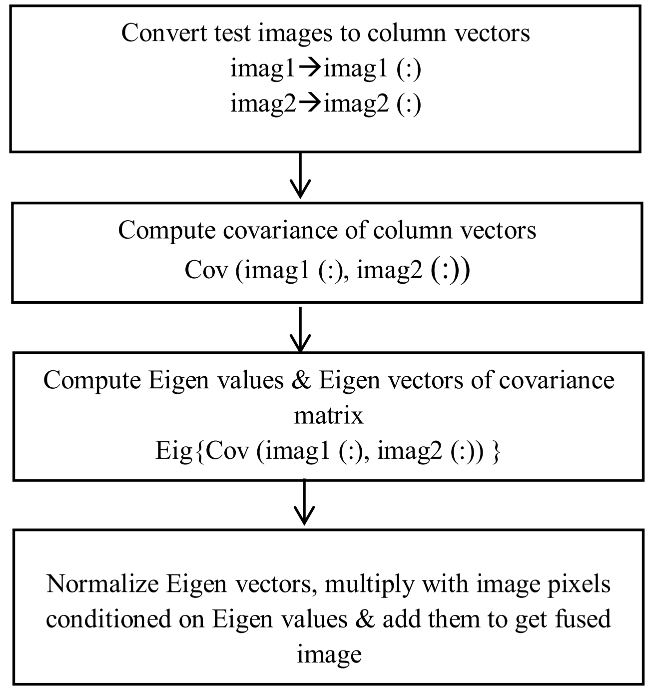


Fig 2.Flow Chart for Image Fusion using PCA

D. Wavelet based fusion algorithms

Wavelets have proven to be good multi resolution analysis tool.The test images are decomposed into their wavelet co-efficients and then fusion rules are applied as explained in the below algorithm.For example test image1 can be decomposed into approximate and detailed co-efficients as shown in Fig.3.The process of image fusion using DWT is as follows.

1. Decompose the source images using *wavedec2 ()* which result in three details sub bands and one approximation subband (HL, LH, HH and LL bands respectively).
2. Then take the maximum of approximate parts of images.
3. Take the absolute values of horizontal details of the image and subtract the second part of image from first.

D = (abs (HJLJ)-abs (HJ+1LJ+1))>=0

4. For fused horizontal part make element wise multiplication of D and horizontal detail of firstimage and then subtract another horizontal detail of second image multiplied by logical not of Dfrom first.
5. Find D for vertical and diagonal parts and obtain the fused vertical and details of image.
6. Fused image is obtained by using*waverec2 ()*.

ISSN: 2278 – 909X

International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
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Fig 3. Onelevel decomposition of test image 1

Similar steps can be used to obtain fused image using Stationary Wavelet Transform using *swt2() and iswt2()* functions.

IV. NETWORK MODEL AND EVALUATION PARAMETERS

A. Network Model

We have considered the simple network model that is shown in Fig. The set of assumptions made are

i. The source group consists of the fixed set of nodes 1,2,3,4,5 which are assumed to be camera enabled.
ii. Node1 is assumed to capture the one test image 1 and so on which are shown in Fig.
iii. Ideal channel is exists between the nodes.
iv. Nodes are available to transmit image at any instant of time.

The work at shell can be put in the flow short shown in Fig. It may happen that not all the nodes deployed have sufficient bandwidth to transmit the fused image. Thus we have found the route through the bandwidth constrained nodes as shown in Fig.

Node1, 2,3,4,5 capture the imag1, image 2, image 3, image 4 and image 5 respectively in which only one feature is prominent. Thus instead of transmitting the images as they are captured to the sink and fusing the images at the sink images are successively fused starting from node 2 which fuses image 1 and image 2. Node 2 transmits fused image to Node 3.Node 3 fuses image 3 andpreviously received fused image .Finally fused from the Node 5 is routed to the sink.

B. Image Fusion Evaluation Parameters

The fused image is evaluated in terms of Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Correlation, Signal-to-Noise Ratio (SNR), Mutual Information (MI), and Measure of Structural Similarity (SSIM) as given in [5] with respect to the reference image.

C. Network Evaluation Parameters

WSNs are energy and time constrained. Less the latency and energy consumed more favorable the scheme for improving the lifetime of the network.

(i) End-to-End Delay(D_{EE})

In a packet switched network the end-to-end delay is the time taken for a packet to be transmitted across a network from source to destination [11]. This is the time taken by image to reach sink from node. This is given by equation (1).

$$D_{EE}=N_h\,[D_{pg}+D_t+D_{pc}] \quad (1)$$

$D_p=D/S$

$D_t=N/R$

Where$D_{pg}$is Propagation delay , D_t is Transmission delay, $D_{pc}$is Processing delay, D is the distance between nodes, S speed of radio wave in the wireless media, R is the bit rate of the link between the nodes and $N_h$is number of hops [12].

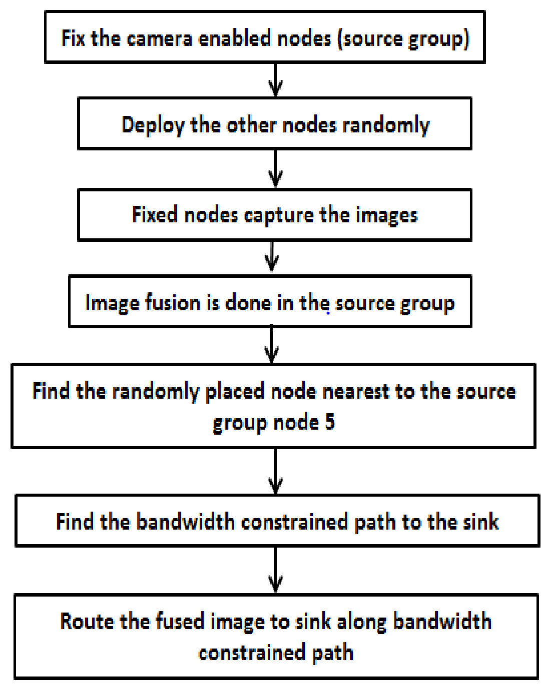

Fig 4. Flow chart for transmission of fused image along bandwidth constraint route

In a packet switching network, transmission delay is the amount of time required to push all of the packet's bits into the communication media i.e. the radio in case of WSNs.This is the due to the data-rate of the link. We have considered 250Kbps i.e. for Zigbee compliant network. D_t is a function of the packet's length and it is proportional to packet's length in bits. D_t is independent of the distance between the twonodes.

Processing delay is the time it takes routers to process the packet header. Processing delay is a key component in network delay. For simplicity since header is not that much bigger in WSN we are considering this as the time required

ISSN: 2278 – 909X

for image fusion at the node. Different algorithms have different processing time which results in variation in the end-to-end delay.

(ii). Energy Model

A very simple radio energy model is considered from [10] given by

$$E_{bit(TX)} = Ea^* \, d^2 + E_e \qquad (2)$$

$$E_{bit\,(RX)} = E_e$$

Where E_a is energy dissipated in Joules per bit per m^2,E_e is energy consumed by the circuit per bit, D is distance b/w TX & RX. These values for mica 2 are E_a = 100E-12 J/bit/ m^2, E_e = 40E-9 J/bit. For calculating the energy consumed by the node we have taken power consumed in active state by the node times the time of execution.

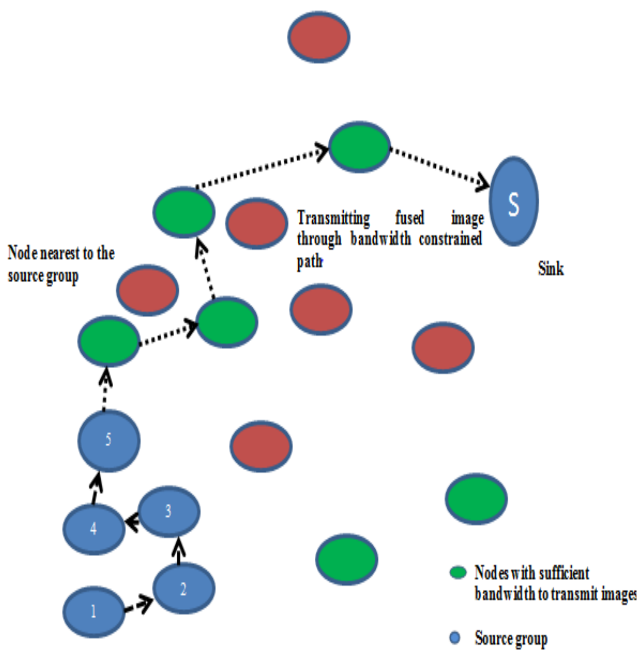

Fig 5. Considered Network topology

V.RESULTS AND DISSCUSSION

Five registered test images considered for successive image fusion along the source group shown of Fig.8 areshown are shown in Fig.6. We can observe that only one feature is evident each of the images. Goal of our work is to fuse them successively at the nodes instead of transmitting individual capture images.

From Fig. 7, Table. I and Fig. 9 we can observe that primitive fusion algorithm averaging gives worst performance. Therefore we can't prefer it even D_{EE}due to it is very minimum. The other primitive algorithm select gives maximum relatively good result in this context. If tradeoff is to favor simplicity, time it is good choice compared to DWT. Though SWT is shift invariant it introduces long delay. Though DCT is widely used in compression technique it is time consuming we can opt for DWT so as to fuse and compress images prior to transmission.

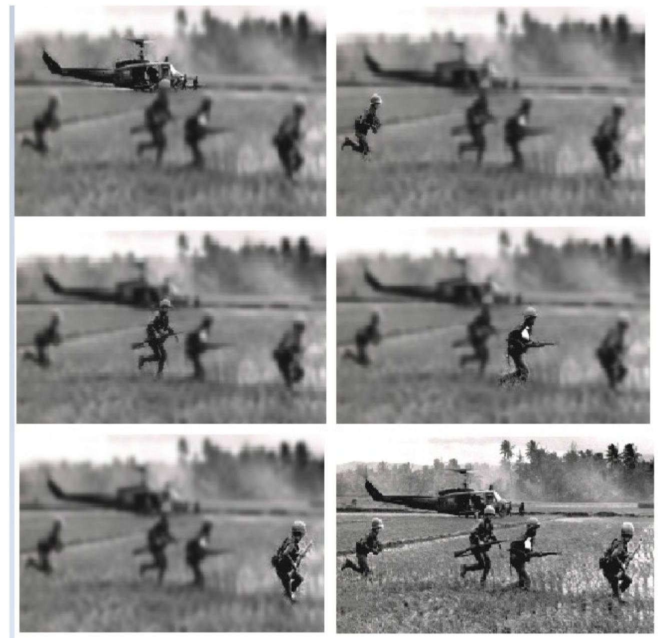

Fig 6. Test images and last image is the reference image taken from www.pythiapress.com

Fig 7. Fused images obtained using averaging, select maximum, PCA, DCT, DWT, SWT respectively (in sequence starting from left most image)

ISSN: 2278 – 909X

Par./Alg.	Avg.	Sel. Max	PCA	DCT	DWT	SWT
RMSE	47.5681	18.8074	19.9060	17.2679	16.3526	16.2730
MAE	31.2904	13.0479	13.9811	11.8255	11.2495	11.1957
CORR	0.9350	0.9916	0.9904	0.99286	0.9936	0.9938
SNR	9.7420	17.8018	17.3087	35.7924	19.0166	19.0754
MI	1.0890	1.1363	1.1363	1.1489	1.1474	1.1480
SSIM	0.451	0.5555	0.5193	0.5918	0.5989	0.6047
QI	0.1586	0.3253	0.2792	0.36606	0.3637	0.3789

VI. CONCLUSION

WSNs are evolving to yield vast applications. The image fusion techniques available in the field of image processing and analysis having greater complexity and computations. Thus choice of particular technique for image fusion effects the lifetime and latency on the network. We have given an account of effect of choosing the averaging, select maximum, DCT, PCA, DWT, SWT techniques with respect to time delay and energy consumption. It can be concluded that we have to go for wise tradeoff between resolution of the fused image , energy consumption and the latency. In our proposed work though select maximum is trivial , resulted as a good technique if we don't need good resolution.

VI. FUTURE WORK AND SCOPE FOR RESEARCH

Our future work aims at implementing the algorithms with much real network model considering the each layer effect in detail. Processing and analysis having greater complexity and computations have to be smartly modified to to exploit image fusion flavor in WSN. Since WSNs are energy constrained ad-hoc networks energy aware distributive nature of these algorithms along with taking advantage of the compression techniques, error resilient multipath routing would better suit the scenario.

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ISSN: 2278 – 909X

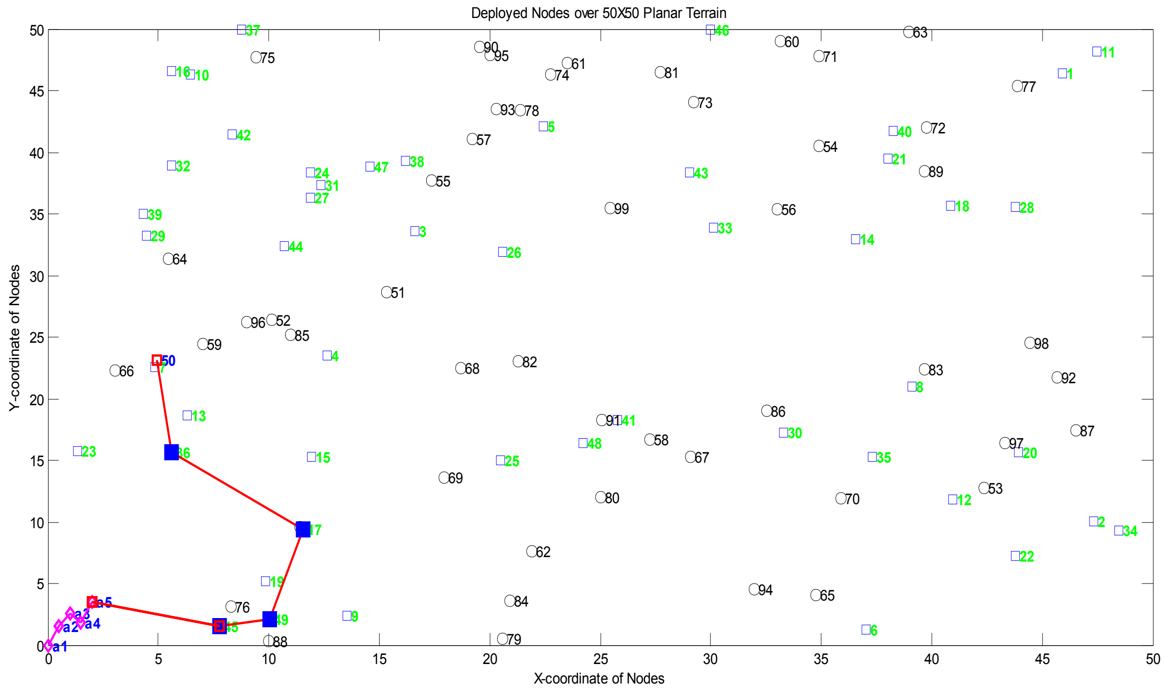

Fig 8. Network topology and the routing path with 50th node as sink

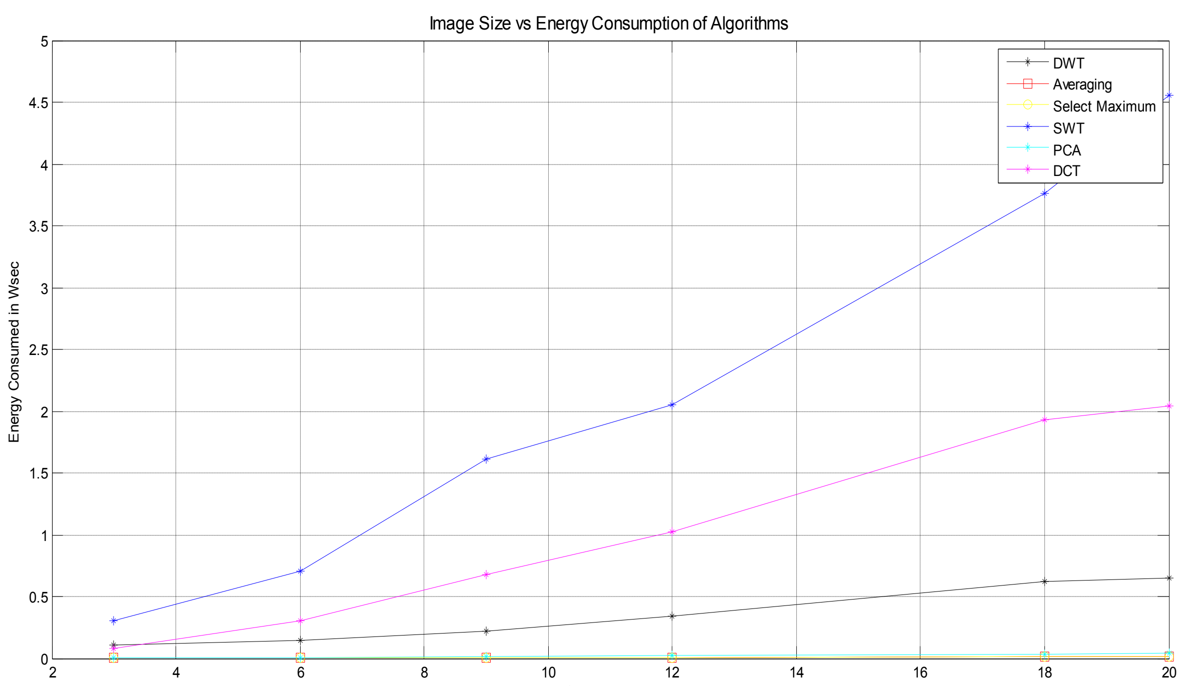

Fig 9. End-to-end delay due to various fusion methods over 50meters/10 hops routing path shown in Fig.8

ISSN: 2278 – 909X

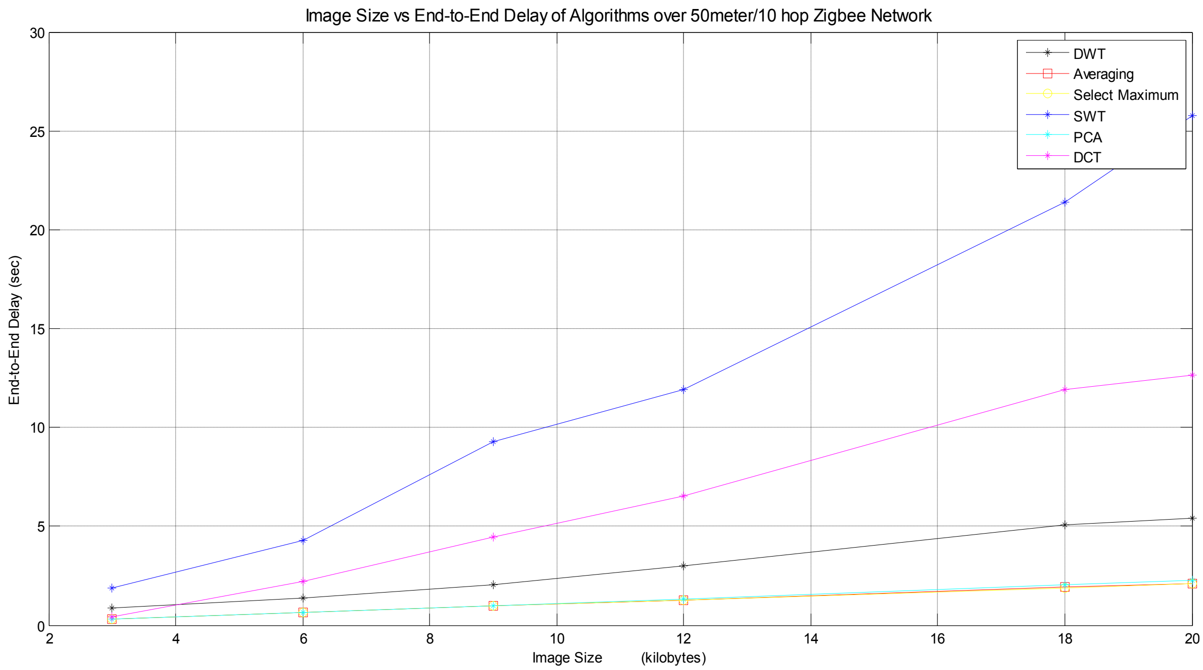

Fig.10 Energy consumption versus image size

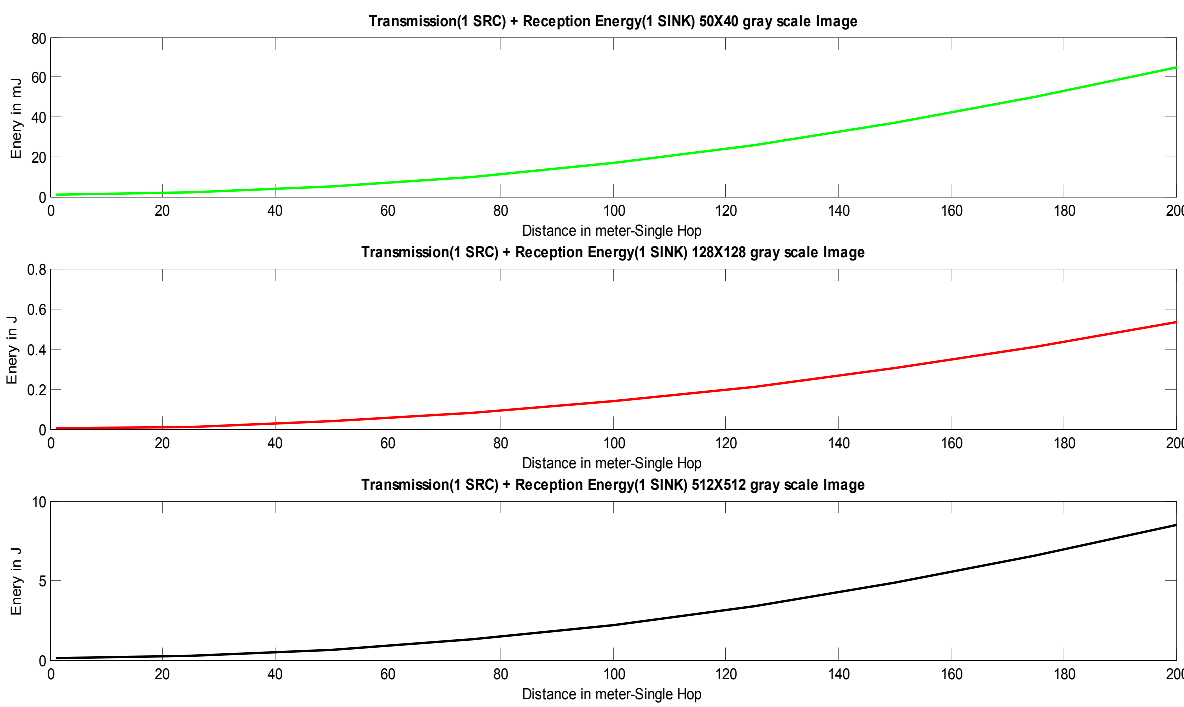

Fig.10 Energy consumption versus distance

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