

A new Leach protocol based on ICH-Leach for adaptive image transferring using DWT

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Abstract

Nowadays, the rapid development and the miniaturization of CMOS image sensors in the last years allowed the creation of WMSN (Wireless Multimedia Sensor Network). Therefore, transferring images through the network becomes an important field of research. The main goal is to transmit the data from a sensor node to another to reach finally the Sink node. Thus, routing protocols play an important role in managing and optimizing the node's resources particularly the energy consumption. Therefore, some routing protocols are known by their ability to save energy and extend the lifetime of the network such as Leach protocol and derived variants. However, multimedia content transferring was not a priority for these protocols. In this paper, the main idea is to adapt ICH-Leach, for image transferring. This protocol was tested in a previous work and has given good performances against Leach, balanced Leach and MLD-Leach. In fact, the Haar wavelet transform is used, in the application layer, to extract the resolution level to be used in image transmission, depending on the rate flow between the sensor node and the sink node. This paper provides statistics concerning the lifetime of the network, the energy consumption and statistics related to receive images using the peak signal-to-noise ratio (PSNR). The Castalia framework is used for simulation, obtained results show the efficiency of the proposed approach by network lifetime extending and more images transmitting with better quality compared to other protocols.

Keywords: DWT, ICH-Leach, LEACH protocol, MLD-Leach, OpenCV

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1. Introduction

The rapid development in micro-electro mechanical system has allowed the miniaturization and the low cost of sensors. They capture information from the environment (pressure, temperature, etc...), and transform them into electrical signal in order to be treated by the processor unit [1]. After getting the information, the sensors either send it to other sensors or store it. Actually, resources of sensors must be optimized efficiently because of multiple limitations such as memory, data processing, power of communication and most importantly energy. In fact, energy is responsible for the lifetime of the sensors. It's essential to take care of this issue [2].

WSN (Wireless sensor network) is composed of several sensors. Each sensor sends the captured data to the base station. Actually, many application fields use WSN like Airport Logistics [3], Security [4], health [5-9], natural disasters [10-12] etc. It is characterized by the following constraints: high bandwidth demand, resource constraints and application-specification [2]. However, routing protocols in WSN consume a high portion of energy. As a result, it affects the lifetime of the network. In fact, there are two kinds of routing protocols: Planning protocols and clustering protocols. The first kind considers all the nodes at the same level. Actually, this category includes multiple routing protocols such as Multipath routing ring [13], GPCR [14], multipath routing protocol [15] etc. The second one organizes nodes into groups called clusters. Many routing protocols are ranged in this category, such as Leach, MG-Leach [16], ICH-Leach [17], and M-Leach [18], Leach [19] etc. These protocols could be applied to multimedia data transferring, without exploring his spatial and spectral characteristics. The Figure 1 shows a WSN.

WMSN is formed of sensors that can capture and transmit multimedia content, such as audio, video streams and images. It has multiple architectures that could be used. The first one

is the single-tier flat in which sensors are homogeneous and the processing is distributed. The second one is the single-tier clustered which has a heterogeneous nodes and concentrated processing. The last one is multi-tier which has heterogeneous nodes and distributed processing. In order to transmit multimedia data perfectly, the WMSN needs some QoS requirements [18]: The limitation in term of resources, the lack of high band, the use of cross-layer and the coding of multimedia content. Many compression techniques can be applied to images in order to reduce the amount of data to be transferred. We can apply DCT [8] (the Fourier transform) on spatial domain.

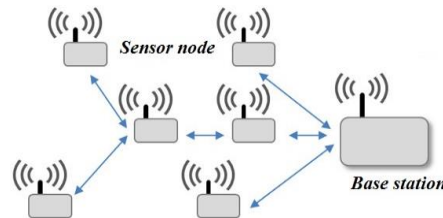


Figure 1. The Wireless sensor network (WSN)

The Figure 2 shows an example of an image reconstitution using the DCT compression technique. Also, we can use discrete wavelet transform (DWT) [20]. A wavelet uses functions that represent a signal with better resolution in time and frequency. The Haar wavelet transform can be applied multiple times, depending on the resolution to be reached. At the first time, we apply a low pass filter on rows to get sub-bands. After that, we apply the high pass filter on columns to obtain four sub-bands LL1, LH1, HL1 and HH1. Then, we can apply the same process to LL1 sub-band to get LL2, HL2, LH2 and HH2. After that, we repeat the same process as many times as we want to LL i sub-band depending on the rate flow between the node and the sink. With high rate flow an image with high resolution can be used. In the Figure 3, the image (a) shows the original image. The image (b) shows the results after the 2D Haar wavelet transform with resolution level 1.



Figure 2. The Reconstruction of the image using DCT technique
(a) original image (b) reconstruction of image using DCT



Figure 3. The 2D Haar transformation applied to an image with resolution level 1
(a) original image (b) reconstruction of image using DWT

In this paper, we used The Leach protocol and its descendants for image transferring. Actually, many improvements have been made since the original version of Leach. In fact,

this protocol saves energy [19]. On the other hand, using them for image transferring is a challenge because of their nature of working [11]. In our work, we improved our protocol by adding the DWT transform in application layer to reduce the amount of packet for each sent image. Also, we took in the account the state of the state of the link between the node who want transmit and the Sink. So, the resolution level varies in function of that link. Then, we compared it with many versions of Leach.

The results showed that our protocol not only extends the lifetime of the network, but can transmit more images compared to other protocols. In this paper, we will expose the related works firstly. Then, we will expose our ICH-LEACH. After that, we will outline our application and discuss results obtained using ICH-Leach, MLD-Leach, M-Leach and Leach.

2. Material and Method

2.1. Leach Protocol

In 2000, Wendi B. Heinzelman proposed a protocol called LEACH which use a series of equal period of time called rounds. Each round comprises of two steps: cluster setup phase and steady pace. In the first one, nodes decide to be cluster-head or not for the current round by picking a random value between 0 and 1. The chosen number will determine if the node is a cluster-head or not by comparing it with the threshold $T(n)$.

$$T(n) = \begin{cases} \frac{P}{1 - P * (r * (r \bmod \frac{1}{P}))}, & n \in G \\ 0, & \text{else} \end{cases} \quad (1)$$

In the (1), P is the wanted percentage of cluster-heads, r is the actual round and G is the list of nodes that have not been elected cluster-head in the last $1/P$ rounds. When a node elects itself as a cluster-head, It must not be chosen again in the next $1/P$ rounds. Each cluster-head of the current round advertises itself by broadcasting an invitation to all other nodes. When the non cluster-head nodes receive that invitation, they decide to join the cluster-head which has the strongest signal intensity. By forming the clusters the setup-phase ends. Then, the cluster-head will assign for every member node a limited period of time of transmission called frames. In each frame, the nodes will be allowed to send their data to their corresponding cluster-head using TDMA. In the steady phase, the nodes send their packets to the cluster-head during their specific frame. The Figure 4 shows this process.

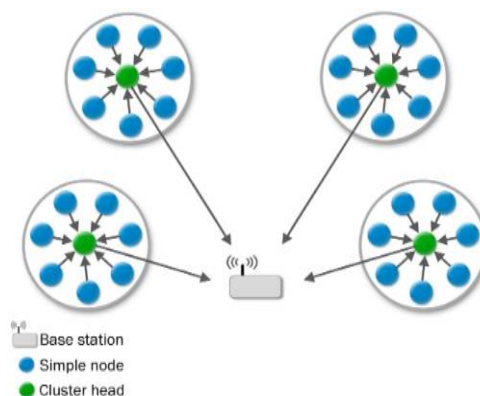


Figure 4. LEACH process

2.2. M-LEACH Protocol

Leach has several drawbacks even if it makes energy consumption a priority compared to plane multipath routing protocols. First, the cluster-heads communicate directly to the sink which causes congestion and high energy consumption of transmission. Then, the cluster heads that are far from the sink will not be capable to reach the sink. For this reason, multiple

improvements of leach were developed to overcome these drawbacks. M-leach is one of these protocols. It uses multipath to transmit data by making cluster-heads intermediate nodes to reach the sink. The intermediate cluster-heads are chosen following the shortest path to the base station.

2.3. MLD-LEACH Protocol

MLD-Leach is a protocol that uses the notion of layers that start from the sink. After the formation, cluster-heads of upper layers have a periodic update of delays with cluster-heads of lower layers as shown in Figure 5. In transmission phase, the cluster-heads of each layer, choose the cluster-head of lower layer which has the minimum delay then the minimum distance.

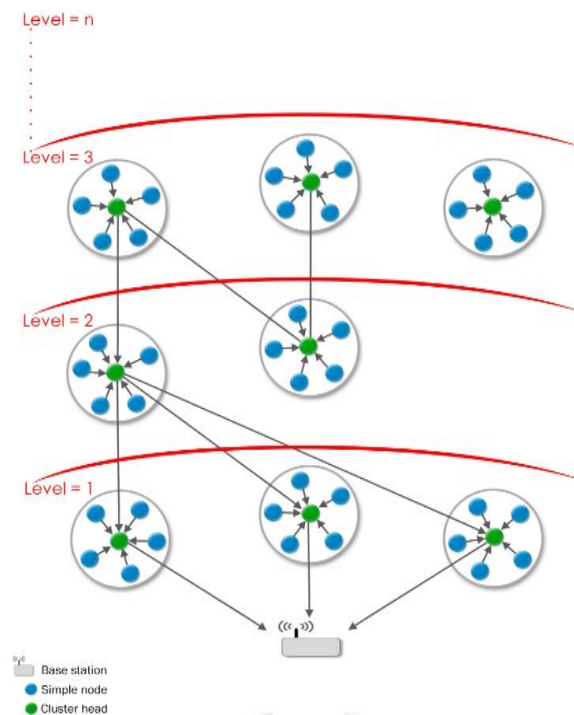


Figure 5. Multilayer structure

3. ICH-Leach Protocol

ICH-Leach is an improved Leach protocol that extends the lifetime of nodes by reducing the energy consumption and sends more images to the base station. Our protocol follows the same steps of Leach, and uses the same percentage of cluster-head. To send more images from a cluster-head to the base station in one hop, data transmission needs high energy consumption [16]. Furthermore, if a cluster-head can't reach the sink the data is lost. Thus, by using cluster-head as intermediate node the consumed energy is reduced and the number of sent images is high even if the distance is far from the base station. The intermediate cluster-head in the Figure 6 is picked based on the position of the sink, position of the cluster-head and the position of the intermediate cluster-head. Thus, a cluster-head can reach the sink no matter the distance.

3.1. Initialization Phase

At first, the base station advertises its position by diffusing a packet that contains its position to the network using the maximum transmission of energy. When a sensor receives the packets, it saves the position of the sink and the signal strength of the received packet. Then, the node starts the election process. If it elects itself as a cluster-head, it retransmits the packet by adding its coordinates. Thus, the formation of clusters begins. The stored position of the sink will help the cluster-head to decide whether or not to send data directly or not.

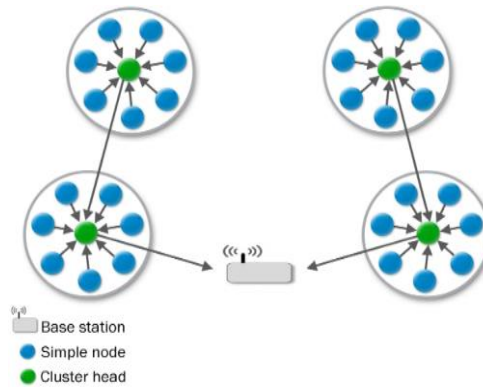


Figure 6. ICH-LEACH transmission process

3.2. Cluster Auto-organization

The Figure 7 shows the cluster formation of our protocol.

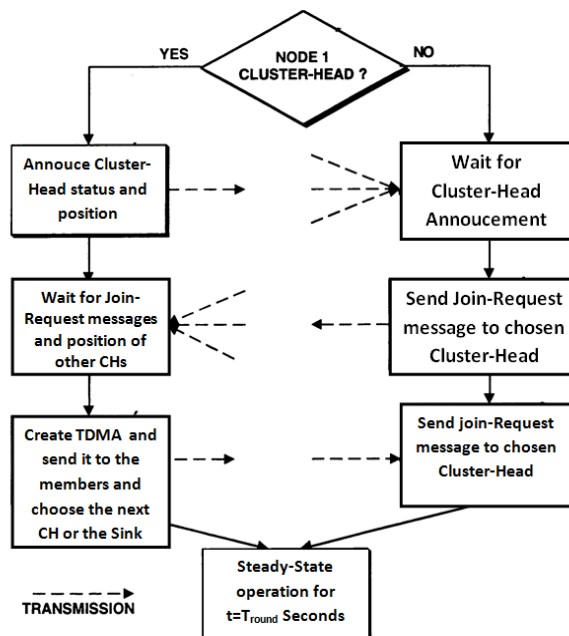


Figure 7. ICH-LEACH cluster process

3.3. Update Process

The update process is initiated by the Sink. By sending the update packet to all accessible Cluster-heads, who receive the packet measure the throughput of the link. Then, they broadcast the same packet with the measured debit. This process is repeated until all cluster-heads get the packet. When a member node receives this packet, it adapts the resolution level that we want to get according to the throughput that he got based on Table 1. Actually, the base station, repeats this process periodically.

debit of the link in Kbps	Resolution level
≥ 100	1
$100 > \dots \geq 75$	2
$75 > \dots \geq 50$	3
$50 > \dots \geq 25$	4

3.4. Transmission process

In this phase, the cluster-heads transmit their data to the base station if it is the closest node. However, it sends them to the intermediate cluster-head if the sink is not reachable. If a cluster-head receives a packet, it saves it until its turn comes.

4. Results and Discussion

4.1. Application Layer

In our application, a number of nodes send images randomly. Before sending images to the network, we apply a resolution level based on Table 1 using the Haar wavelet transform. Then, we send the image and the diagonal wavelet to network with the applied level. Once the sink receives the data, it reconstructs the image by applying the reverse Haar transform based on the received resolution level. The Figure 8 shows this process.

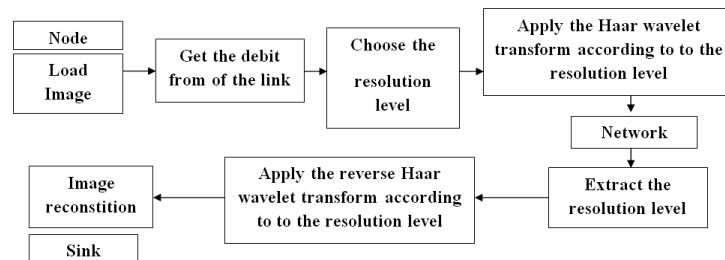


Figure 8. Compression and decompression process of images

4.2. Simulation Parameters

In this paragraph, we will detail the simulation parameters and the results that we obtained. We used the framework Castalia to make our simulations, and used the radio model CC2240 [21] to replace a real radio transmission. In fact, the number of rounds is too small because of the radio and the effect of round length on multimedia transfer [22]. Also, we compared ICH-Leach with the original leach, M-leach and MLD-Leach. In our simulation we suppose that the sink can't reach all the nodes. The Table 2 shows the proprieties that we used in our simulation.

Table 2. Simulation parameters

Parameter	Value
Topology size	200x200m ²
Number of nodes	200
cluster-heads probability	0.05
Number of trials	40
Initial power	40j
BS position	(0,0)
Size of image	512x512
Number of sent images	30
Delay between images	300s
Delay between sending packets	0.2s

4.3. Analysis of Results

In this paragraph, we will evaluate our protocol using two approaches. The first approach is the duration of the network and energy consumption per rounds. In fact, this parameter shows us how a routing protocol is efficient in term of extending the lifetime of nodes that form the network and energy consumption. For multimedia transferring, we are going to use different metrics. The first one is measuring the number of images per PSNR [23-25]. Actually, that allows us to measure the quality of received images. The second one is measuring the lost packets during the transmission that shows us how the network reacts in term of delivering packets. The Figure 9 shows the energy that is consumed by the entire network. It shows clearly that leach protocol has the highest energy consumption among the four. Tested protocols. Nevertheless, ICH-leach consumes lower energy compared to other protocols.

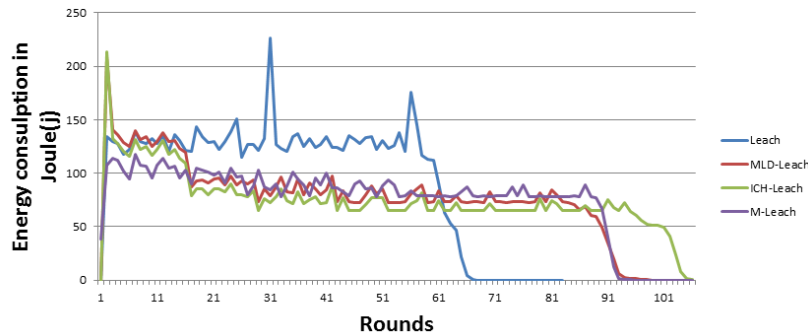


Figure 9. Energy consumption per round

These results could be explained by the fact that Leach uses a full energy transmission to reach the sink. Thus, the energy consumption per round is high, compared to other protocols. M-Leach and MLD-Leach use multiple hops, which helps to minimize energy consumption per round of the network compared to Leach. Finally, ICH-Leach uses at maximum two hops based on the position of the base station and the node source. Thus, the energy consumed by the network is reduced to the minimum.

The Figure 10 shows the number of dead nodes with respect to the four different protocols. Concerning Leach, we denote that the first node dies in Round 58 and the last node dies in Round 64. It also shows that the lifetime of nodes is shorter compared to other ones. In M-Leach the first sensor dies early in round 90, but the last node dies after leach in round 92. In MLD-Leach, the first node dies in round 20, and the last node dies in round 98. Finally, our protocol has the best performance in term of duration of life of the network. In fact the first sensor dies in Round 100 and the last node dies in round 104.

In the original protocol, the high energy consumption per round due to the full energy transmission causes the short duration of the network comparing to the other ones. On the other side, M-leach leads to longer lifetime compared to Leach. Multi-hop in M-leach uses intermediate cluster-heads to reach the sink node based only on distance, this can causes an overload os some cluster-heads. Hence, it has a direct effect on these cluster-heads by dropping their energy faster than others as depicted in Figure 10, this causes the death of some nodes die in the first rounds. The MLD-leach gives a longer network lifetime compared to M-Leach, even if both of them use multi-hop. This result can be justified by the fact that the amount of intermediate cluster-heads depends on the number of layers from the sink. Finally, the ICH-Leach proves more consistency and extends the duration of the network compared to other protocols, and can send data to the sink on one hope if it is the nearest. Otherwise, the cluster-head chooses the nearest cluster-head As an intermediate cluster-head. Also, the transmission power is adjusted according to next node. This policy has two benefits. First, reducing network congestion, second, economizing energy, which is confirmed by the obtained results in Figure 8 concerning energy consumption of all network nodes. The Figure 11 shows that most of the constructed images have a low PSNR. Thus the quality of the constructed is low.

In Figure 12, the M-Leach can transmit few images with high PSNR (100 %). The rest of the rest of received images has a low PSNR. In the Figure 13, MLD-Leach has a high numbers of completed images with high PSNR. In Figure 14, the ICH-Leach has the highest number of images with higher PSNR. Also, more than 95% of received images are received with a quality 100%. The Figure 15 shows that ICH-Leach has the minimum number of lost packets and high number of high quality images.

We can explain these results by many reasons. Results obtained with Leach protocole can be explained by the network congestion, caused by the single hop from cluster-heads. High number of lost packets shown by the M-Leach results are caused by the high amount of intermediates cluster-heads. For MLD-leach, results can be explained by the fixed number of intermediate nodes with respect to the number of layers and varying the next node depending on the network stat (distance and delay). Thus, we have less congestion and less lossed packets. Finally, results of ICH-Leach can be explained by the fact that one intermediate node is used at most. So, less congestion around the sink and less packets in the buffer.

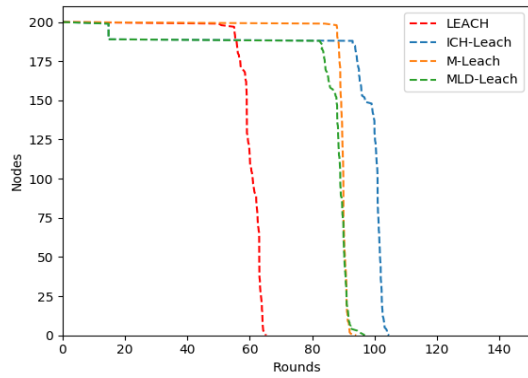


Figure 10. Dead node per protocol

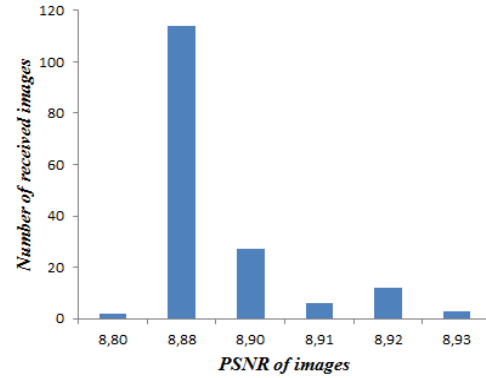


Figure 11. Number of images per PSNR using LEACH protocol

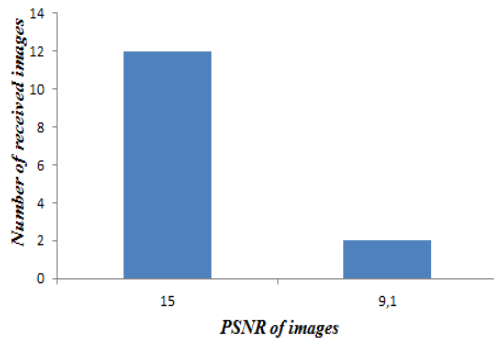


Figure 12. Number of images per PSNR using M-LEACH protocol

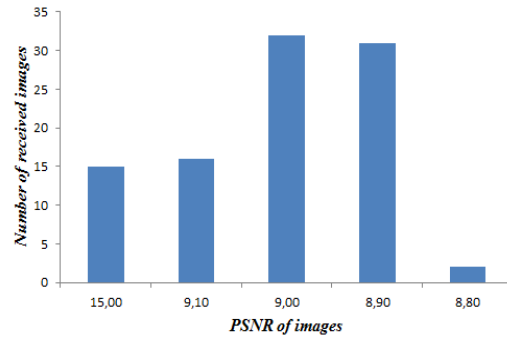


Figure 13. Number of images per PSNR using MLD-LEACH protocol



Figure 14. Number of images per PSNR using ICH-Leach protocol

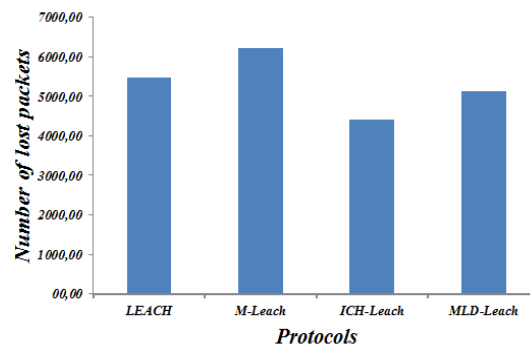


Figure 15. Number of lost packets per protocol

5. Conclusion

During this work, we adapted the ICH-Leach to image transferring by taking the debit between the node and the sink into consideration. This parameter determines the resolution level of the Haar transform to be used. As a result, the number of packets during transmission process is reduced. After comparing our customized protocol to Leach descendants, we found that ICH-Leach increases the quality and the number of transferred images and reduces energy consumption. Thus, the lifetime of the network is extended. Also, the high number of intermediate nodes, which is an issue related to M-Leach and MLD-protocols. In fact, this

problem creates a high waiting list of packets. Thus, the combination of our protocol and DWT technique is more suitable for image transferring.

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