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Short Article

A Study on Energy Efficiency in Wireless Multimedia Sensor Networks

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ABSTRACT

Wireless Multimedia Sensor Networks (WMSNs) consist of cheap sensors which transmit real time multimedia data to each other or to a sink. Audio and visual information may exist in a single device. Besides, WMSNs are able to store real time data after gathering it from several sensors. But since both the size of transferred data is big and the difficulties to reach the areas where WMSNs are used, network lifetime of WMSNs and their energy become a vital requirement. Using energy in an efficient way is also necessary for a network not to lose its functionality. What kind of solutions are considered in the literature for WMSNs and its analysis are given in this paper. First, where the WMSNs are used is shortly mentioned and then, the studies related to energy efficiency are investigated.

Keywords: *Wireless Multimedia Sensor Networks, Energy Efficiency*

Kablosuz Multimedya Algılayıcı Ağlarda Enerji Verimliliği Üzerine Bir Araştırma

ÖZET

Kablosuz Multimedya Algılayıcı Ağlar (KMAA), gerçek zamanlı multimedya verilerini (ses, resim ve video) birbirlerine veya baz istasyonuna aktaran ucuz donanıma sahip algılayıcıların oluşturduğu ağlardır. Tek bir cihazda ses ve görsel bilgi bir arada bulunabilir. Bunun yanında, KMAA'lar gerçek zamanlı veriyi birçok algılayıcıdan alarak depolayabilmektedirler. Ancak, gerek aktardıkları verilerin boyutlarının fazla olması gerekse kullanıldıkları bölgelere ulaşmanın zorluğundan dolayı KMAA'larda ağ ömrü ve enerji çok önemli bir gereksinim haline gelmiştir. Ayrıca, enerjinin verimli kullanılması ağın işlevini kaybetmemesi için de gereklidir. Bu çalışmada, KMAA'ların enerji sorununa literatürde nasıl çözümler getirildiği ve ne şekilde incelendiği ele alınmıştır. Öncelikle KMAA'ların kullanım alanları kısaca bahsedilmiş ve daha sonra da enerjinin verimli kullanılması ile ilgili çalışmalara yer verilmiştir.

Anahtar Kelimeler: *Kablosuz Multimedya Algılayıcı Ağlar, Enerji Verimliliği*

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I. INTRODUCTION

IT is not an unexpected situation that we need information more and instantly in the developing world. These needs become unable to be satisfied by wired communication techniques as the time passes. Therefore, wireless communication has taken the place of wired communication. Wireless network communication technologies are also preceded with wireless communication. Wireless Sensor Networks (WSNs) have pervaded easily for the reasons like being convenient to nature conditions, being reliable, having a flexible structure, producing low-cost solutions, being self-organized, using its energy well balanced in the network, and ease of configuration. The purpose of WSNs is to provide easy access to information at anytime from anywhere. They perform this duty by collecting data, processing, analyzing, and then broadcasting it.

Recently, WSNs have gained attention of researchers since they are able to solve theoretical and practical problems easily in the field of data transmission. The reason of this rising attention is using small and cheap devices to transmit data through far distances after performing simple operations on WSNs in a physical environment. WSNs are used to measure some physical phenomenon like temperature, pressure, moisture, and position. Many military and civil applications are developed with WSNs recently [1].

Networks are divided into two groups: structured and randomly distributed. WSNs are in randomly distributed networks group and they are distinguished from structured networks in terms of some features. The most important difference is efficient energy consumption since these networks have limited battery power and have to work for a long time. These networks do not have a certain topology. Data is transmitted through nodes, it arrives to base station, and it becomes something that operations can be done on [2].

CMOS cameras and microphones which have cheap hardware are started to be used recently to catch surrounding multimedia (video and sound streams) content. Thanks to the improvements in hardware, sound and visual data can exist together in one device. WMSNs are able to store real time data by gathering it from several sensors and transmitting it to base station similarly [3]. WMSNs comprise the most promising developments in real time multimedia surveillance. However, resource requirements like network lifetime and energy become burning issues of WMSNs since transmitted data amount is quite big when compared to WSNs [4].

II. USAGE AREAS OF WMSN

The data gathered via WMSNs is in the scope of some study areas like signal processing, control theory, and embedded computer systems in terms of communication and computation [5]. WMSNs have been used in some new applications such as surveillance, traffic application and control systems, advanced health services, structured health monitoring, and industrial process control. Since sensor nodes and video cameras in WMSNs have high computation capacity, they facilitate many applications [6].

WMSNs are mostly used for surveillance purposes. Monitoring systems against crime and terrorism attacks are developed using video and audio sensors [5]. Also, classifying the images gathered by WMSNs increase the usability of the application substantially [7].

The idea of using small scale habitat monitoring systems also for monitoring people and even improving those systems bring the concerns related to its effect on public order and legal rights. Security, privacy and social effects of those networks must be considered as well with the maturity of those systems [8]. Implementing those networks into the habitats of plants and animals may create psychological and physical effects on those organisms. Physical disorders caused by constant data flow may affect organisms negatively and these applications which basically aim to heal their lives may deflect the purpose and damage the ecosystem. Furthermore, WMSNs are frequently used to monitor vehicle traffic and to dispel congestion. WMSNs located on highways are also used to obtain some information like average speed or number of vehicles on the road [5]. In addition, there exist smart parking systems based on WMSNs. These systems help drivers by monitoring park places and so relieve city traffic [9].

Another application of wireless sensors is wearable sensors. Patients can be controlled at any time by their doctor through wearable wireless sensors [10]. Studies this topic and develops an application of WMSNs to be used in medical area. Wearable wireless body area network (WWBAN) application is developed in the paper.

Moreover, WMSNs are also used for enjoyment purposes. Besides individual games, there is a rapid increase in the number of games that are played as a group on the network recently. WMSNs which are studied in that area provide users to control their senses simultaneously and make them feel inside the game. Therefore, WMSNs have made those games more popular [5].

In many environmental applications, images can be recorded by watching the environment on video, and then required information can be achieved based on those records [11]. Pressure, moisture, and temperature values can also be used for the development of the industry besides the images. It can be used to detect defects and to control quality of the products in the manufacturing process. Furthermore, WMSNs gain flexibility for visual inspection and automatic action systems which require permanent working and they facilitate the integration of machine recognition systems.

Additionally, it is mentioned in [12] that industry gained great interest for power grid thanks to WSNs. Sensors used in power grid as a standard bring only measurement values, but this information is expressed as limited. A new generation power grid has been developed against this system. Variety of applications has been developed in power stations. A low-cost wireless motor monitoring system which measures line voltage and flow has been developed to evaluate motorized energy used in a permanent station [13].

III. Studies Related to Energy Efficiency for WMSN

Energy consumption is the most important design limitation in wireless sensor networks because wireless nodes work with a limited battery. It is required to reduce power dissipation as much as possible to increase lifetime of each node [14]. Since data amount in WMSNs are greater than that of WSNs, their energy consumption is more. Some algorithms are developed to process data gathered from surrounding nodes in WMSNs. Next, unnecessary data is not transferred and therefore both transferred data amount and energy consumption is reduced. For example, data may be compressed or not completely transferred in video security applications [15].

C. Sha and others [16] intended to improve this subject by examining economical transmission methods. Data gathered by sensors is compressed using an algorithm without any loss in the quality of

images or videos. Therefore, they claimed that energy saving can be provided during data transmission. E. Sun and his friends [17] goes to one step further and mentioned that they can minimize energy consumption by minimizing data amount without any deterioration in image quality thanks to the algorithm they developed called as Low Energy Image Compression Algorithm (LEICA). Also, they proved that LEICA prolongs network lifetime in WMSNs according to simulation results of their application.

Most of the nodes in a network spend most of its lifetime in sleep mode to reduce energy consumption [2]. Habitat monitoring applications have to work for months or years and therefore, a node has to spend most of its life in sleep mode. Sensors wake up only for periodical sampling, calculations, and communication. Time spent as awake for each node is known as duty cycle and different approaches perform cyclic operations with low power [18].

Important issues related to energy in WMSNs are great amount of data and deficiency of communication strategies for proper processing architecture. Packet loss rates and retransmission causes inefficiency in terms of energy and bandwidth. A. Seyd and his friends [19] developed a new architecture and a protocol considering these deficiencies. They developed these to provide video communication over applicable, reliable, and efficient wireless sensor networks. They combined Discrete Wavelet Transform (DWT) with the architecture and the protocol they developed for the purpose of reducing transferred data amount and energy consumption. Application layer protocol includes an efficient queue control strategy to reduce packet loss rate. Results of the study show that the approach reduces energy cost significantly [20].

Mulugeta and friends proposed a secure routing protocol for sensor networks in [21]. Energy has been used in minimum level during compression, processing, and transmission of data in this study. Similarly, a protocol called EECM (Energy Efficient Congestion Avoidance) has been developed for WMSNs to improve video quality, to reduce packet loss, and to provide energy saving. It is proved that 5% energy saving is achieved with this protocol [22].

As we mentioned above, many energy-sensitive applications have been developed for WMSNs. [23] proves with simulations that images in JPEG 2000 format can be transferred with less energy and without any deterioration in visual quality in WMSNs thanks to developed algorithm. Image size is reduced by removing redundant bits in the image with this algorithm and it is argued that transmitting fewer amounts of data reduces energy consumption. [24] proposes a sound compression algorithm for WMSNs.

An Artificial Immune System (AIS) based image recognition application for WMSNs is given in [25]. It is mentioned that total energy consumption and recognition scope changes with respect to modes of sensors whether active or sleep and it is argued that the study shows compatibility for minimum energy cost during data processing in large-scale images.

An 8.39 times reduction in data amount is achieved when compared to JPEG with the algorithm developed in [26]. The algorithm is SOM (Self Organizing Map) which is a machine learning algorithm used for dimension reduction. This method is an unsupervised learning model. Sensed image is coded by the proposed algorithm and forwarded to base station with a forwarding algorithm. Coded data is decoded in base station and the original image is obtained back. SOM provides the best convergence to the original data set by finding a subset which best reflects the huge input set. Proposed method uses this vector quantization feature to compress image data. SOM is used in code table design. Produced code table is stored in base station and every node. Two operations are

performed to transfer image and regenerate it in base station: encoding and decoding. In encoding phase, received image is divided into blocks and corresponding code words of each block is found in code table. Then, it is transferred to base station. In the decoding phase, transferred code word is transformed to a code vector.

Besides, placing nodes affects network performance, capacity, latency, efficiency, and energy consumption significantly in terms of forwarding [1, 27]. In a study related to node placing in [28], a mathematical formula is given to calculate the locations where the nodes will be placed and the nodes are placed according to this formula. Thus, the energy of the network is proved to be used efficiently via simulations performed.

Table 1. *Classification of methods*

Reference	OSI Layer	Solved Problem	Used Algorithm or Technique
17	Application	Compression and energy consumption	LEICA
16, 19, 20	Application	Compression and energy consumption	DWT
21, 22	Network + Application	Compression, energy consumption and transmission	EECM
23	Application	Compression and energy consumption	JPEG2000
24	Application	Compression and energy consumption	DCT
18, 25	Network	Energy consumption	Mode of Sensors
26	Network + Application	Compression and energy consumption	SOM and JPEG
28	Network	Energy consumption	Node Placing

IV. RESULTS

Main problem in WMSNs is how to use the energy efficiently. Because, different from ordinary WSNs, there is a larger amount of multimedia data flow. As shown in Table 1, there exist different proposals in different studies in the literature for the solution of that problem. Some of the protocols [18, 25, 28] given in proposals are related to network layer. In those protocols, some energy issues like congestion in network traffic and idle nodes are tried to be solved. In the other studies [16, 17, 19, 20, 23, 24] some image and voice compression algorithms to work on application layer are proposed. It is seen that except [21, 22, 26] hybrid approaches have not been tried. Data sizes can be reduced without distortions in image quality thanks to newly explored hybrid methods and multimedia data flow between nodes and sink can be implemented in a more efficient way after a proper routing protocol is selected.

As a future work, lossless resizing and compression techniques which are frequently used in image processing can be adapted to wireless networks considering the physical limitations of sensor nodes. Also, multimedia data can be classified and specialized nodes for various duties (video, audio, and text transmission) can be used. Each node can take and process its own data. Energy cost will then be decreased because the operation speed is shortened.

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