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MEASUREMENT OF ENERGY CONSUMPTION OF WSN FOR INDOOR ENVIRONMENT

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Abstract

A wireless sensor network (WSN) is a wireless network consisting of distributed autonomous devices using sensors to observe physical or environmental conditions. The energy consumption is very important for WSNs. The paper presents that measurement of the energy consumption of indoor environment. Ti CC2538 modules were used as WSN nodes and they were programmed via Contiki Operating System (OS). Simulator of Contiki OS is COOJA. The program was simulated with COOJA before being tried in real life. Then, measurements were taken directly from the module via Labview and DAQ card. The network used Low Energy Adaptive Clustering Hierarchy (Leach) protocol which is a very popular networking protocol for WSN. The nodes in the network were prevented to go in sleep mode. Therefore, measurements showed transmit and receive mode energy consumption. On the other hand, cluster head election period and transmission period of sensed data selected as short as possible to make measurements in a short time. The proposed measurement system can be used evaluate any new networking protocol more realistically.

Key words: *WSN, Contiki OS, COOJA, energy consumption, LEACH.*

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1. Introduction

Wireless Sensor Network (WSN) is a wireless networking class that consists of distributed sensor nodes to monitor physical or environmental conditions such as temperature, sound in different environments [1]. The application areas of WSNs are increasing depending on the developing technology. Every kind of environment has a flexible and dynamic networking capability that can be easily adapted [2]. WSNs may contain thousands of sensor nodes. In most cases, the nodes are randomly placed, making it difficult to determine their location. In these cases, it is difficult to scale the accuracy [3]. In addition, data transmission in WSNs is fast and cost-effective. However, sensor nodes are limited in their use due to battery limitation. Since sensor nodes have limited batteries, they transfer their data to a central base station. If the amount of data transmitted by various techniques is reduced, communication and energy costs are also reduced. Data collection and compression methods can be used to reduce the amount of data. However, this option may not always be enough. Optimization of the sensor storage unit becomes important in such situations. Today, numerous researches have been done to minimize the energy consumption of the nodes [4,5]. At the same time, a number of protocols have been proposed to reduce the energy consumption of the nodes the least. One of these is the Low Energy Adaptive Clustering Hierarchy (LEACH).

LEACH is proposed by Winde B. Heinzelman et al. [6]. One of the most popular cluster-based routing protocols in wireless sensor networks is Low-Energy Adaptive Clustering Hierarchy (LEACH). The cluster formation process is based on the received signal strength in LEACH. LEACH clustering algorithm does not guarantee about even distribution of cluster heads over the network. This is disadvantage of LEACH. It is supposed that each cluster head transmits data to sink over a single hop. LEACH protocol has deficiencies. These are

1) Some very big and very small clusters may exist at the same time in the network.
2) Cluster head selection can't be true if the nodes have different energy.
3) Cluster member nodes consume energy after cluster head was dead [7].

LEACH is energy saving, a hierarchical protocol that balances energy consumption. It keeps the energy of the nodes in order to extend the life of the network [8]. This selects the cluster head using energy and position information. At the same time, the cost function also accounts for when making the selection [9].

Contiki OS is used for coding of LEACH based protocol in this paper. Contiki was offered in 2004. Contiki is an open source, highly portable, multitasking operating system for memory-efficient networked wireless sensor networks and embedded systems. Contiki is programmed in the C language [10].

COOJA is a simulator designed for simulating networks of sensors running the Contiki operating system. COOJA simulates networks of sensor nodes where each node can be of a different type; software or hardware. COOJA is flexible because it allows that many parts of the simulator can be simply replaced or extended with additional functionality. A simulated node in COOJA has three basic features: its data memory, the node type, and hardware peripherals [11].

The paper organized as following: Second section include proposed method; experimental results are showed in the third section. Conclusions are placed in the fourth section.

2. Proposed Method

Energy consumption has been examined with an approach based on the LEACH protocol. The main goal in LEACH is to determine cluster heads.

The generated random value and predetermined threshold value are used to select cluster head. The generated random value is selected as the cluster head value below the predetermined threshold value (T(n)). T (n) is calculated using equation 1.

$$T(n) = \begin{cases} \dfrac{P}{1 - P[r \, mod(1/P)]} & if \, n \in G \\ 0 & otherwise \end{cases} \quad (1)$$

Desired percentage to become a cluster head is shown P. The current round is repsesented with r. G is the set of nodes that have not been choosen as a cluster head in the last 1/P rounds [12].
Each node produces its own random value, but calculation of the threshold value is same each node. If the node declares itself as a cluster head, it reports this to the other nodes via the broadcast message. However, if the node has a random value above the specified threshold value, the node is not cluster head. And it will send packets of its to the cluster head. Since the distance information is obtained with the RSSI value, the RSSI method is used to determine the nearest cluster head. The closer the distance between the nodes, the larger the RSSI value. Among the nodes that can read the RSSI value, the node with the greatest RSSI value is the selected cluster head. The address information of the selected cluster head is read at the same time as the RSSI value. Thus, when the RSSI value is decided, address information becomes available. All nodes that specify the cluster head send unicast messages to the cluster heads. Cluster heads gather received messages from nodes and transmit base station. This event is shown Fig. 1.

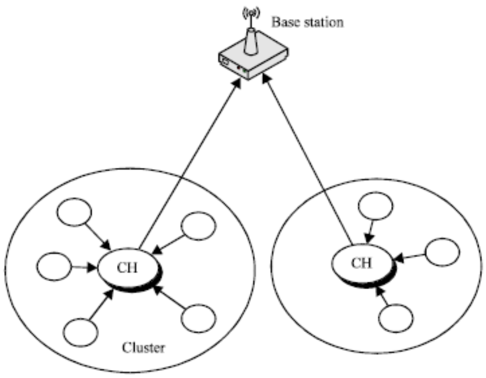

Fig. 1. LEACH Clustering.

All these events will occur during the specified timer. There is a timer defined. The timer is to decide whether the node is cluster head. At the same time, node is not allowed to be cluster head again until all nodes are cluster heads. This process continues like this. The flow diagram of the event is given in Fig. 2.
In our work, we used Contiki OS to transmit and receive data in WSNs. The protothread structure of the contiki operating system is used. Thus, the program parts run synchronously. Thus, the program gain time. The program was simulated with COOJA before being tried in real life. The simulation output is shown in Fig. 3.
There are fifteen nodes in COOJA simulation. One of the nodes is sending broadcast to nodes of its influence surface as Fig. 3.
The written program was firstly tried in COOJA simulation. Then the written program has been transferred to the Ti CC2538 module. The number of module used is five. One of these modules is base station. The written program is transferred to the Ti CC2538 module using “Flash Programmer 2”.

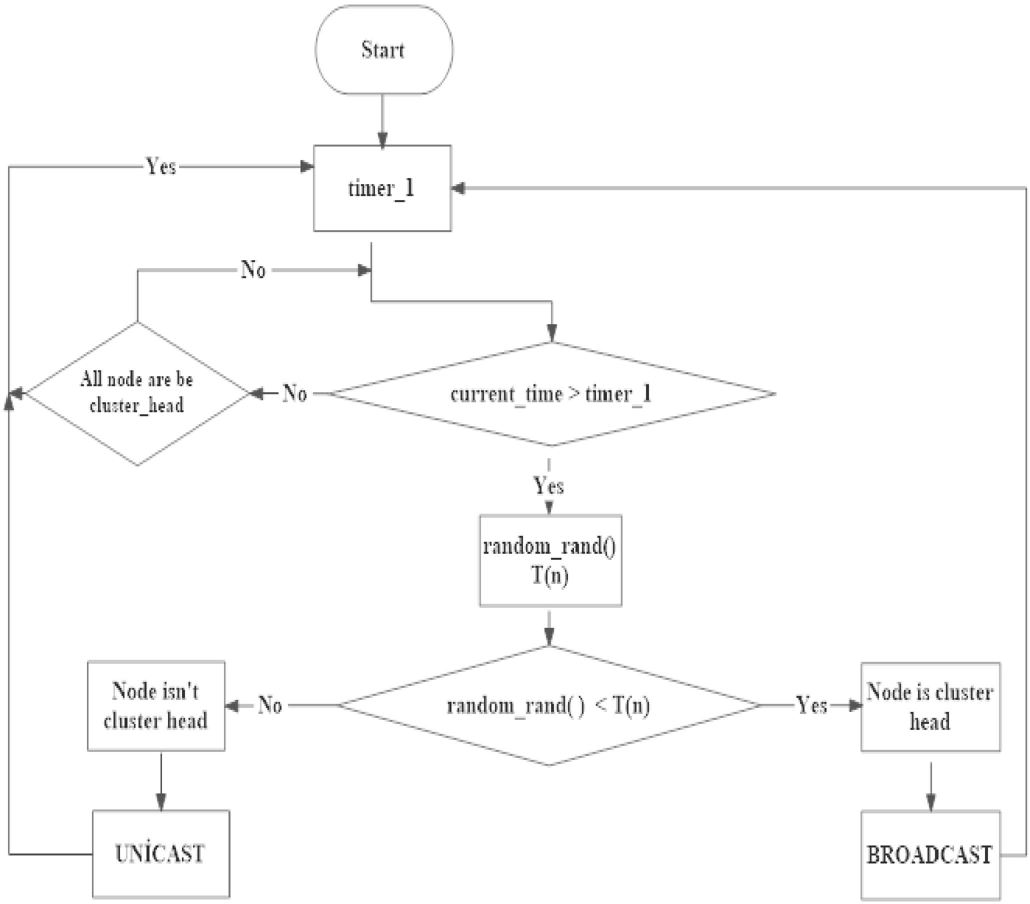

Fig. 2. The flow diagram of the method.

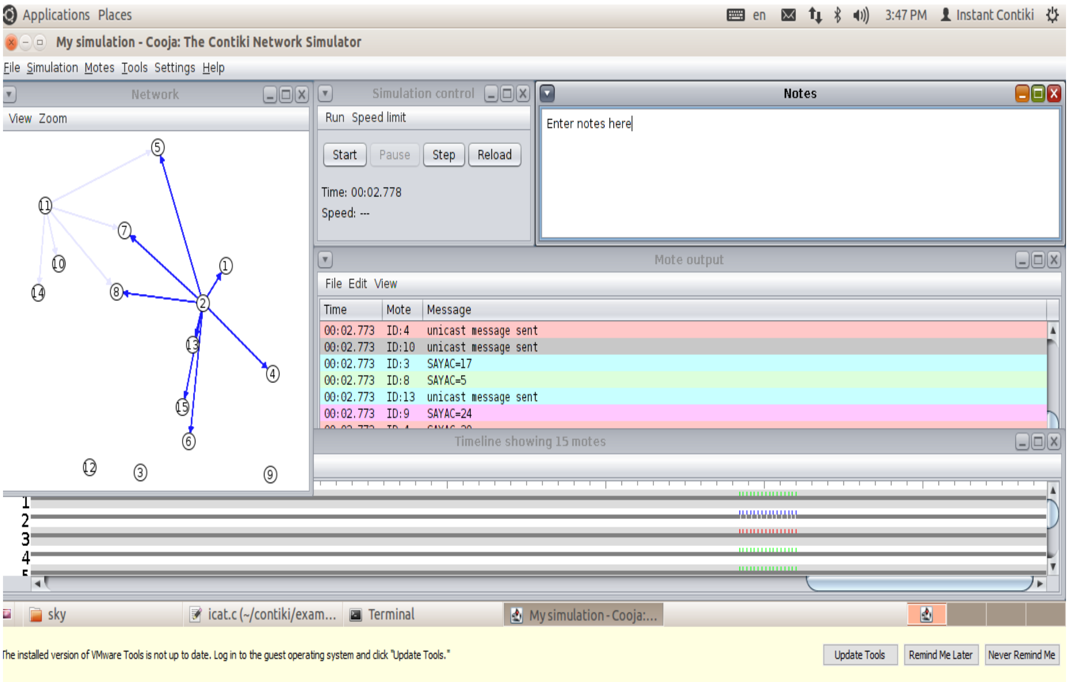

Fig. 3. The COOJA simulation.

Measurements were taken directly from the module via Labview and DAQ card. Fig. 4 shows output of Labview program.
Fig. 5 is shown that positions of Ti CC2538 modules in real life. Base station is linked to laptop with USB cable. Other modules gets its power from other computers.

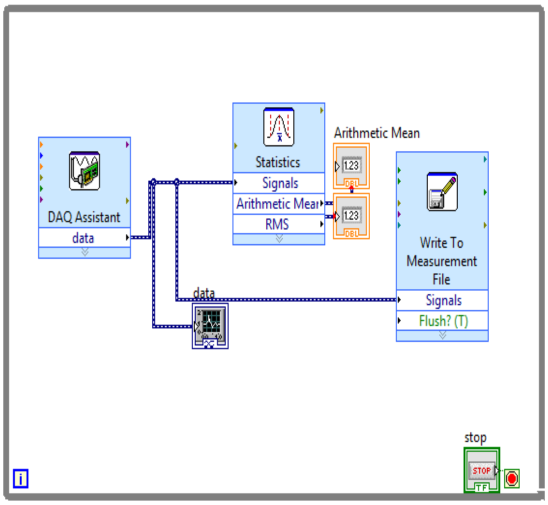

Fig. 4. Shows output of Labview program.

Fig. 5. Simulation in real life.

3. Experimental Results

Measurements were implemented at Electric – Electronics Engineering Department of Karadeniz Technical University.
The energy consumption of network was measured as highly depends on distances between nodes. The measurement chart is shown in Fig. 6.

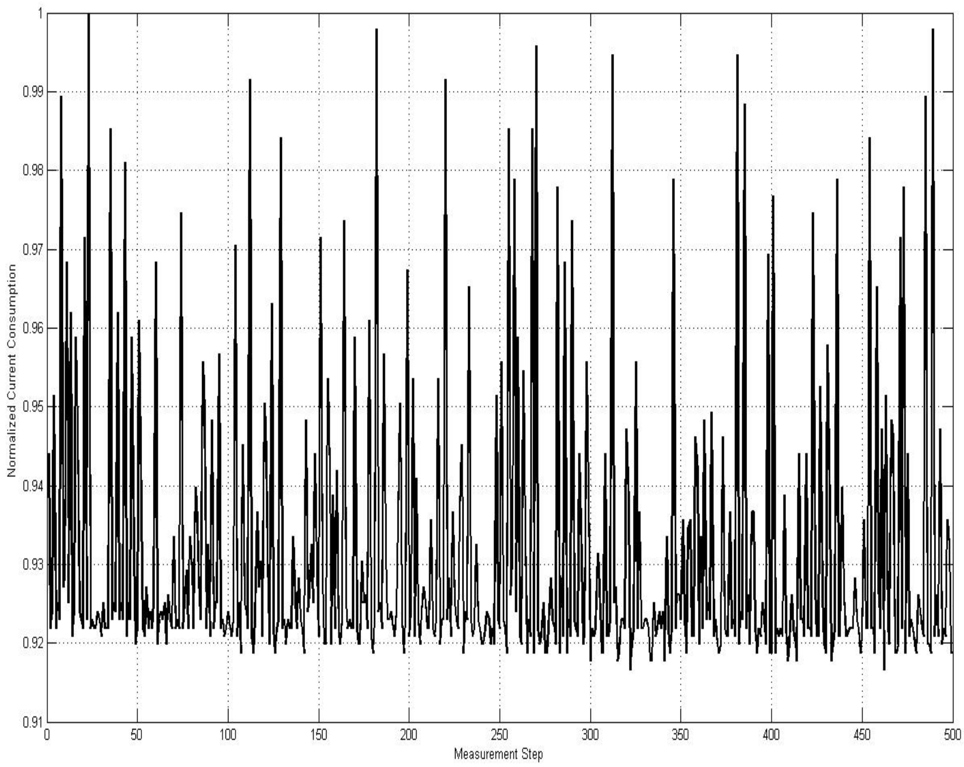

Fig. 6. The measurement chart.

The x-axis of the graph represents the measurement step. Measurements are taken in 10 ms steps. The y-axis of the graph represents normalized current consumption. Normalized current consumption value varies from 0.92 to 1. Measured maximum current is 32.24mA. All of the measured current values are normalized by the maximum current. The current value is not going to zero because the nodes are not allowed to go in sleep mode. On the other hand, the nodes send their sensed data to cluster head frequently. Not allowing sleep mode and shortening period of transmission are done for getting significant measurement results in a short time.

Because of same transmission medium is used there may be collisions. The measurement results also show energy consumption when a collision is met by a node. If the normalized current consumption value is close to 0.92 the node is in receive mode. When normalized current consumption is close to 1 the node in transmit mode. According to LEACH algorithm nodes should calculate threshold value if they are in cluster-head election mode. Because random number generator and some calculations are made in cluster-head election mode CPU of the node should consume more energy. According to measurement results nodes consume 29.8mA average current. Total measurement time is 232 seconds. If the nodes were transmit their data when an event occurred they were be in sleep mode and would consume as low as 2μA current [13]. Fig. 7 shows time steps when the node consumes more current than average.

Fig. 7. Transmit mode time steps for a node.

It is assumed that if the node consumes more current than average it is in transmit mode. If a node in transmit mode the following may be happening:

- The node is sending its data to the cluster head (unicast messaging)
- The node is sending broadcast message after cluster-head election period
- The node is sending message to sink because of it is elected as cluster head.

Fig. 7 includes all of the possible transmission situations above.

4. Conclusion

The energy consumption of indoor Wireless Sensor Networks (WSN) were measured. Ti CC2538 modules were used as WSN nodes and they were programmed via Contiki OS. Measurements were taken directly from the module via Labview and DAQ card. Low Energy Adaptive Clustering Hierarchy (Leach) protocol which is a very popular networking protocol used as networking protocol in the nodes. Nodes are not allowed to go in sleep mode and frequency of being in transmission mode is increased for getting significant measurement results in a short time. The proposed measurement system can be used evaluate any new networking protocol more realistically.

On the other hand, taking into consideration the effect of packet error rate (PER) would provide more realistic results on energy consumption. It is advisable to make a measurement system that includes packet error rate calculation in future works.

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