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# A Low Energy Consumption Media Access Control Protocol for multi-level Body Networks using two Different Radio Channels

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***Abstract*****----** *In this paper, a low energy consumption media access control protocol for multi-level body networks is proposed. In this protocol, we use a wake-up mechanism to reduce energy consumption of radio, so that the sensor nodes sense the patient's vital signs and the sink node sends data through an additional channel in order to receive the data of body vital signs and it starts sending the data after the wake up of sensor node. The sensor nodes send data to the sink node using IEEE 802.15.4 standard. The sink node is a device like a mobile device that receives data from nodes using IEEE 802.15.4 standard and sends it to a server's wireless access point after processing with IEEE 802.11 standard to be deployed on the local network or the Internet. The proposed method is simulated with Glomosim simulator and compared with the Leach method. Simulation results show the superiority of the proposed method.*

***Keyword*****----** *Energy efficiency, lifetime, media access control, routing, sensor networks.*

## I. INTRODUCTION

Nowadays, with the growth of new technologies, creating low-power sensors, small sizes, and affordable prices are possible. These sensors have limited processing power, sensitivity, transmitting and receiving radio, which varies according to their application[1]. In the wireless body sensor networks, the sensors are scattered over a body. Due to importance of energy consumption, latency and control overhead in physical wireless sensor networks we should take some special measures in communication, topology, routing and data processing because energy consumption, delay and control overhead in wireless sensor networks of the body are the most important challenges[2]. One of the applications of wireless sensor networks is the monitoring of human health. In order to achieve that a large number of small sensors are placed on the body or inside of human body. These sensors together create a wireless body area network and monitor the vital signs and signals of the human body and send it to the doctor. One of the most important applications of the wireless body area network is the implementation of the patient's health network in the hospital environment. In wireless body area networks, these factors mainly include energy efficiency, versatility, channel efficiency, and delay. Energy consumption is the most important challenge in wireless body area networks, which leads to an increase in network lifetime and increase the efficiency of this type of network. In the proposed method, we use a wake-up mechanism to reduce energy consumption of radio, so that the sensor nodes sense the patient's vital signs and the sink node sends data through an additional channel in order to receive the data of body vital signs and it starts sending the data after the wake up of sensor node. The sensor nodes send data to the sink node using IEEE 802.15.4 standard. Related works

In this section, the previous approaches that improve the media access control protocol in wireless body area networks have been addressed.

The [29] is about case networks. The idea of a separate channel is to wake up the radio alongside the main radio channel that is used in wireless body area networks. The additional radio channel consumes much less power than the main channel and causing a deep sleep state of the main radio and thus optimizes energy consumption. The main problem of WUR is additional hardware overhead. In [30] they provided a media access control protocol with three basic processes for link establishment, wakeup service and alarm process. In this protocol in order to prevent collisions, the Wakeup Fall-back Time (WFT) mechanism has been used. In WFT mechanism, if a node wants to communicate with the sink node and cannot do it due to activity of the sink node, it will go to sleep mode for a specific time that is calculated by the WFT and the data will be buffered continuously over sleep time. This protocol has some problems, such as idle listening and overhearing.

In [31] a TDMA-based protocol was proposed for wireless body area networks, which is called Med MAC. The protocol consists of two schemes for energy saving: Adaptive Guard Band Algorithm and Drift Adjustment Factor. The Adaptive Guard Band Algorithm is used with the time stamp to synchronize between coordinators and nodes. This synchronization, using a guard band between time intervals, allows the node to sleep for many periods. The Drift Adjustment Factor is used to minimize bandwidth and adjusts the guard band according to the actual situation and avoids the overlap between consecutive intervals. Med Mac uses the IEEE 802.15.4 standard to perform zero class (Low data rate applications such as health and fitness monitoring) and it uses class 1 (medical applications with medium data rates, such as EEG). In this method, each device has exclusive use of a channel for a fixed time interval, so the synchronization overhead is reduced. This protocol works for low data rate

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applications effectively and it works inefficiently for high data rates applications.

In [32] a protocol was introduced for wireless body area networks, which is called Low Duty Cycle Mac. In this protocol, analogue to digital transmission is done by nodes and complex tasks such as digital signal processing by the sink node. This protocol introduces the concept of guard time to avoid interference between consecutive time intervals, and after this frame, a network control is used in packets for general network information. This protocol is energy efficient because it sends data in a short time and this protocol effectively overcomes the problem of collision using the TDMA strategy. The problem of this protocol is that it does not work in dynamic topologies.

In [33], the Body MAC protocol was proposed that utilize the energy using three bandwidth management schemes: bandwidth burst, bandwidth periodic, and bandwidth adjustment. The bandwidth burst includes a temporary period that includes bandwidth of multiple MAC frameworks and Gateway retrieval. If the node does not use the total bandwidth, bandwidth is reduced by half, and the node is aware of this bandwidth reduction. The bandwidth periodic predicts the exclusive access to the channel for a node in a part of the MAC frame or several MAC frame. It is also allocated by the Gateway based on QOS requirements of nodes and the current availability of bandwidth [43]. Bandwidth adjustment defines the bandwidth value and increase or decrease it. The dedicated timeframe is free in contention free period and improves packet transferring and energy saving. It also uses CSMA / CA that is not trustable.

In [36], the T-MAC protocol was introduced to increase energy efficiency. In this protocol, the node wakes up after assigning of time slot and the waiting messages are sent and if there are no activation events at a time interval, the node will go to sleep mode. If the node sends a packet and does not receive a clear message, it will re-send the packet before going to sleep. This protocol sends the packets explosively and as a result the delay is minimized. The disadvantage of this protocol is sleep problems.

[37] Suggests that energy efficiency using the Media Access Control Protocol can adjust the transmission power levels of the sensor nodes. Therefore, measuring service quality of wireless network sensor is an important issue to improve the performance and efficiency of these systems.

In [38], a clustering wireless sensor network is proposed to reduce energy consumption, in which fuzzy clustering and routing using bee colonies is performed. This method is not very suitable in networks where there are heterogeneous nodes.

[39], they have focused on the selection and prioritization of the node submission list, which minimizes the energy of all nodes in the wireless body area network. This opportunistic routing, which is called EEOR, reduces network power consumption, delays, and packet loss rates.

In [40], a routing method, which is called CORMAN, is provided for wireless case networks. This new routing method combines link quality with natural playback of wireless channel and causes high quality of transmission. The key features of CORMAN in wireless case networks are improving performance, reducing energy consumption, and reducing the delay of delivery.

In [41], local opportunistic routing protocol called LOR37 is presented using the distribution of an algorithm for selecting the minimum choice for transmitting data in a dynamic topology using local information. The LOR routing protocol improves performance, control of access to independent media for opportunistic routing, control overhead, end-to-end delay, and throughput capability.

In [42], a model-driven framework is proposed to optimize routing for wireless sensor networks. This routing method has removed the limitation for unicast and multicast traffic. The simulation results and the performed experiments show that the proposed method has a shorter route and lower control overhead than the other routing protocols. One of the problems of this approach is that it has inappropriate performance when the network topology and the traffic have changed suddenly.

## II. Suggested Method for Routing with the Lowest Hop

Improvement method, power consumption of media access control protocol using two different radio channels in the network, this research uses two-tier architecture with routing with a minimum number of hops [45]. This two-tier architecture requires new-pitched sink nodes, which improve the network by reducing energy consumption, increasing network lifetime, reducing the number of hops and routing.

## III. Network Architecture of the Proposed Method

The wireless body area network in our proposed model consists of two-layer architecture. In the first layer, the nodes sense the vital signs of the body and uses IEEE 802.15.4 to transfer data to the sink node. In this layer, which uses the radio wakeup mechanism, an additional radio channel is used alongside the main radio channel. The radio wakeup mechanism is one of the best methods that reduces the energy consumption of sensors in a wireless sensor network.

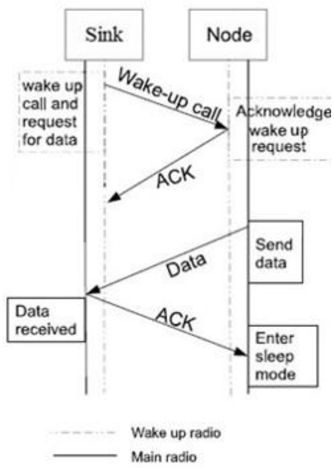


Fig. 1. The sink node sends a request to wake up the radio.

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In this mechanism the sensors that do not have data to send and receive go to sleep mode and wake up to transfer data and then go to sleep mode again when work is done. The task of an additional radio channel is to receive data that wakes up the sensor node. Fig. 1 shows an example of how the sensor data is transmitted with two radio channels.

From the additional radio channel of the node number two The sink node sends a request to wake up the radio from the additional radio channel of the node number two. The second node, after receiving the request, sends a message to the sink node that the data has been received, and then begins to send the data. After completion of sending data and receiving confirmation from the sink node, the sensor node goes to sleep mode. The additional radio channel has a much lower bandwidth than the original radio channel, which cause it to have much more energy consumption than the main channel. Using two radio channels on one sensor has additional hardware overhead, which, thankfully, does not pose a particular problem regarding to the advancement of wireless technology and the shrinking of hardware components in this area. This layer consists of low priority and high priority data stream classes. High priority data include those vital signs that are vital and should be sent so fast, continuously and without delay, such as heart rate. Low priority data include those vital signs that are less important than high priority data, and having delay in sending does not cause problems, such as blood pressure. In the case of transmitting data, it is necessary to transfer high priority data faster than low priority data. The reason for using the IEEE 802.15.4 standard in the first layer is the low power consumption of this standard, which increases the network life time but has a low range, which increases control overhead. In Fig. 2, the first level shows the proposed method that the sensor nodes create a cluster, and after sensing the vital signs of the body, they send the data to the sink node to reach the base station after finishing the second stage of the process.

The second level of the proposed method starts from the sink node and continues to the wireless access point, so that the sink node process the data after receiving it from the sensor nodes according to the IEEE802.15.4 standard and after making the changes sends the data to the wireless access point using IEEE802.11 standard. This layer has two classes of traffic, just like the previous one.

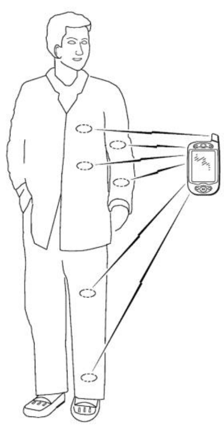

Fig. 2. Method of connecting sensors to the sink node.

The first class is called hard real time, and its task is to send high priority data of the previous layer. The second class is soft real time [44], which transfers low priority data of the first layer.

In Fig. 3, the general architecture of the proposed method has been shown. The sensor nodes sense the vital signs and send the data to the sink node. The sink node has the task of transferring data to the Access Point, and if the sink node could not access it by routing it transfers the data to the neighboring sink nodes.

*Sink Node Architecture*

The sink node in this model is like a mobile device and is easily rechargeable. The sink node receives the data from other nodes according to IEEE802.15.4 standard and sends the data after processing it using IEEE 802.11 standard. The reason for using the IEEE802.11 standard in the second layer is that most of the communication devices support this standard and it has wider range than the standard of the first layer, but it has more power consumption, which cause no problem because the sink node is easily rechargeable.
The sink node consists of three units:

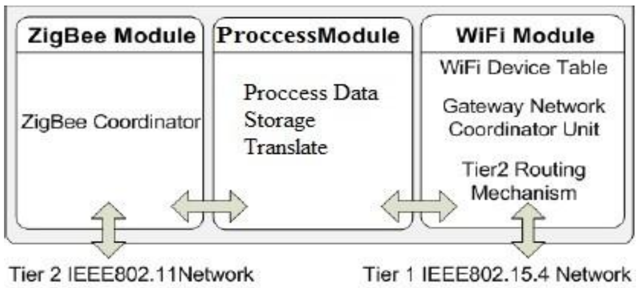


Fig. 3. ZigBee unit & Wi-Fi unit.

ZigBee unit (802.15.4): In the first layer, we use a topology that identifies the sink node of the entire network and connects all sensor nodes located on the patient's body to the patient's sink node using ZigBee. In fact, the main task of the ZigBee unit is to send the sensed information to the sink node on the basis of their priority and to wake up the sensors.
Wi-Fi unit: This unit is divided into two components: a Wi-Fi device table that contains information about Wi-Fi, traffic, data priority, and the used radio channel. A routing that provides all of the Wi-Fi routing needs. In addition to the Wi-Fi unit, there are two distinct messaging frame types: data frames and management frames. Data frames are used for data transfer and management frames are used for specific messages such as: routing methods, Wi-Fi device table update and settings.

*Processing Unit: This unit is divided into two parts:*

Data processing is the most important part of this unit. Processing data for sending, storing, routing and translating is one of the most important tasks in this section.

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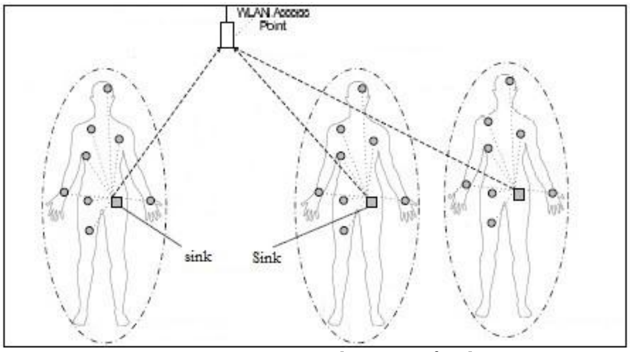

Fig. 4. Communication architecture of a cluster.

The data storage location stores the necessary data and when it is not possible to communicate with the access point and routing is needed, or the sink node is one of the routing hops, it will store and retrieve the data. The translation unit deals with the translation of data between two layers.

*Describe the Performance of the Proposed Protocol*

In this protocol, each part of the hospital is considered to be a cluster and each cluster have a fixed access point to receive data from the sink node. The nodes sense the vital signs of the body and send this information to the sink node using IEEE 802.15.4 standard. Our sink nodes are devices like a mobile phone that has the ability to recharge, process, and coordinating nodes, convert, send and receive ZigBee and Wi-Fi data. The sink node has the list of all the nodes and their priorities. The nodes connect directly to the sink node using IEEE802.15.4 standard, and as a result the power consumption of the nodes become low and they would operate for longer hours. Due to easy charging of the sink node, there is no concern about energy saving in the sink node, and because the sink node give the priority to the top priority data of the first layer, more vital signs will arrive to the server with a lower delay. In the proposed method we try send the data to the sink node for processing as much as possible in order to save energy in nodes and increase network lifetime. The sink node first receives the high priority data and performs the processing on the service unit, and then sends data to the Wi-Fi unit to be sent to the Access Point in hard real time traffic. Low priority data are similar to high priority data, except that they are sent in the soft traffic class. Now, if the access point of a cluster is stopped for some reason, we should send the data to the access point of other cluster via routing, which we need to do routing to reach the access point of other cluster. The routing method plays a significant role by interacting with all or a part of the network nodes and its impact on energy consumption, network life time, end-to-end delay, control overhead, and traffic.

*Routing*

The nodes should sense the vital signs of the body, and the patient's vital signs data should be accessed on local network or the Internet using access point. Hospitals have different departments that we consider each department as a cluster. When the access point of a department or cluster of the hospital goes down, the sink node should be able to deliver its received data to the access points of other clusters via several hops and other sink nodes. In order to do this routing we should consider the delay and control overhead to have the best performance and the least amount of energy used in data transferring. Reducing the number of hops will result in shorter paths for data transferring, improving the delay, control overhead and energy consumption. To reduce the number of hops, we need to reduce the number of discovered paths.

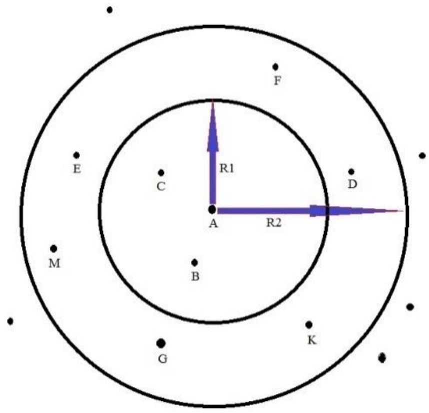

Fig. 5. The proposed routing.

For this purpose, we used two mechanisms for limiting the sending of the request packet and limiting the route based on distance. In limiting the sending of the request packet, we can specify that the source node sends multiple request packets to its neighbors, in which the number of paths are reduced, and the source node is allowed to send a certain number of request packets and all of its neighbors would not receive the packets. In the mechanism of limiting the route based on the distance, the source node divides its neighbors into two parts based on the distance. The first part consists of close neighbors that are within a distance less than the threshold range. The threshold range is the distance that is has been specified already and is the boundary between the close and far neighbors. The second part contains far neighbors, which is at a distance between the threshold distance and the maximum radio range of the sink node.

For routing, when a node needs to find a route to the destination, it first determines neighbors and the number of request packets. Then it sends the request packets to far neighbors. The reason for choosing far neighbors is reducing the number of hops, which leads to less control overhead and delay. Far neighbors will begin to distribute the request packet to their far neighbors after receiving a request packet based on the number of previous permitted request packets. This routine continues to make the route from the source to the destination.
For example, in Fig. 5, the node A is the source of sending data. The threshold of the node A is $R_1$, and the distance R is the radio range of the node, so the close neighbors of node A are if nodes B and C. Also, the far neighbors of the node A are nodes D, E, F, G, K, R, and M. However, if the number of far neighbors exceeds the permitted number of packets, it randomly selects the far neighbors and sends the request packet. If the number of far neighbors is lower than the permitted number of packets, the node sends request packets

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to far neighbors and sends the remaining packets to close neighbors. The number of close neighbors that the source node selects is equal with the remaining request packets from far neighbors.

## IV. Evaluation and Comparison of Research

The biggest challenge for sensor networks, which the wireless body area network also subscribes to, is energy consumption. In order to improve this important challenge in wireless body area networks in hospitals, we have come up with solutions such as: using two radio channels, data classifications, using two communication standards, the shortest path routing and the lowest hop. The results of the above-mentioned solutions are illustrated in the Glomosim simulation software, and are shown in the diagram with Leach clustering, which compares the number of hops, and the death of the nodes.

### A. Energy Consumption

At the first level of the proposed method a radio wakeup mechanism and two separated radio channels are used for waking up the nodes, and at the second level a rechargeable sink node has been used with higher range of communication standard that is used in routing with limiting request packets methods and choosing neighbors with distance far from the threshold and give the shortest path and the lowest hop in sending data from the sink node to the base station. These factors have a direct impact on energy consumption in the body wireless area network and as you can see in Fig. 6, this method has lower energy consumption rate in comparison with other method.

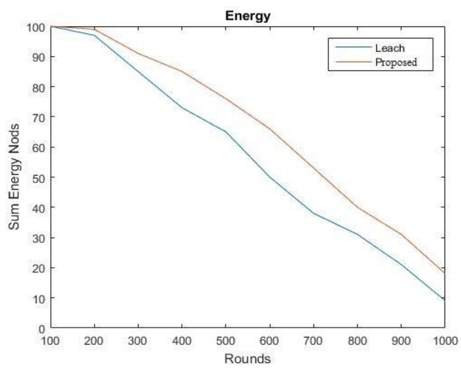


Fig. 6. Energy consumption.

### B. Nodes Death

A set of sensor nodes constitutes a wireless sensor network. The battery embedded in sensor nodes is the only way to provide the required power of these nodes, which is usually not rechargeable. When the energy stored in the battery becomes zero the nodes death happen and as a result they would not have any activity. The death of each sensor node impacts on the performance of wireless body area network, and with the increase of the rate of the death, the network would not be able to do 100% of its task. The lifetime of the wireless sensor network ends with the death of the last sensor node. In the proposed method, due to use of the radio wakeup mechanism with two separated radio channels and the outsourcing of data processing in the sink node, the energy consumption of each sensor node is reduced and, as you can see in Fig. 7, the number of node deaths is lower than the other method.

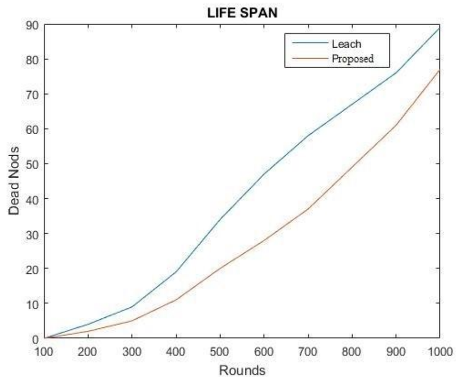


Fig. 7. Node death chart.

As you can see in the above diagrams, energy consumption, node death rate and number of hops that reduce latency and control overhead are improved in comparison with the Leach method.

### C. Number of Hops

The number of hops means the number of times that the packet is received and sent by sink node in routing process. In the proposed method, the number of hops has been reduced because routing between the sink nodes is done with the IEEE 802.11 standard and the number of request packet is reduced and neighbors have been selected far from the threshold range. Reducing the number of hops in routing reduces latency and control overhead, which are the main challenges of wireless body area network.

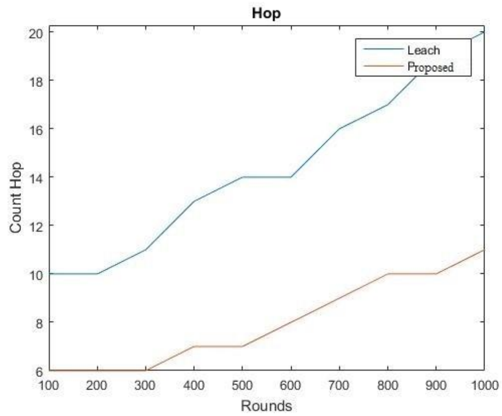


Fig. 8. Hop number chart.

## V. Conclusion

This paper addresses the issue of improving media access control in wireless sensor networks to reduce energy consumption and maintain network coverage. To achieve this, we have used two communication standards that create two levels of network. At the first level the 802.15.4 standard is used because of very low power consumption, and at the second level 802.11 standard is used due to reduce the number of hops which has a high radio range that reduces the number of hops in routing. According to the simulation results, the energy status, the number of hops and the death of the sensor nodes have improved.

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