

The research on the solutions of the energy consumption problem in WSN in medical field

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Abstract. In the last few years, the Wireless Sensor Networks technology has been a hot topic, and depending on its self-organization feature, it has been utilized in many fields. The WSN is a technology that collects different kinds of data from different sensor nodes and processes them to a database center which will provide information to the users. But, because the main tool to collect data is the sensor nodes, the problem of energy consumption will be caused. The article will mainly give the exact reason why the energy consumption problem shows up and pay attention to different solutions to this problem. The solutions are very effective in solving these problems and can be gradually applied in many fields, especially in the medical field, which the article focuses on.

Keywords: Wireless Sensor Networks, Energy consumption, medical, Multi-hop.

1. Introduction

Nowadays, lots of new technology have been created, for instance, Virtual Reality/Argument Reality, Block chain, Big data, and Internet of Things known as IOT. IOT links nearly all the things in this world with the internet, which can make our world a more convenient and better place. IOT is the name of all the technology that belong to it, such as, Radio Frequency Identification, known as RFID, IR sensor and so on. IOT collects different kinds of information and interact the information through all kinds of possible networks which can realize the ubiquitous connection between things and things, things and people and realize the intelligent perception, identification and management of goods and processes. In this article, this work will talk about one of the IOT technology, Wireless sensor networks. Wireless sensor networks are a type of wireless network that includes many cyclic, self-directed, small, and low-power devices, known as sensor nodes [1]. The Wireless sensor network is also named WSN. WSN combines technology that includes embedded technology, sensor technology, wireless communication technology, and so on. WSN means the network has space distribution and dedicated sensors, which can be used to monitor and record the physical condition of the environment and gather the data to the center. The main feature of WSN is self-organization, which means the devices in the network are reciprocity. When in information interaction, they can be the client or the server. The sensor networks cover many spatially distributed, small, battery-powered embedded devices. These devices can collect and process data, and transmit it to operators through the network, which control the computing and processing capabilities. Nodes are some computers but very small and have the function of sensors and work together to form a network. The sensor node is a multi-function and power-saving wireless device. The

node is widely used in the application of industry. The sensors collect data from the environment and approach the aim of the application. In the wireless network, there are hundreds, even thousands of sensor nodes. The application of WSN is very extensive. This article will mainly talk about the application in the medical field. In the medical field, using WSN, the patients will be cared for by monitoring their vital indicators doctors from where they are, this work can let the WSN system keep an eye on the patients' life indicators.

This article will talk about the problem of the system that brings to us and the solutions that experts give to these problems. And the article will show the architecture of WSN, and the problem that energy consumption brings to the system. At the same time, the article will finally discuss the solutions to the problems. There are three algorithms to deal with the problem, named EOMRC, LEACH-improved algorithm, and GBSR. The three algorithms will be based on different kinds of methods to solve this problem.

2. The Architecture of Wireless Sensor Networks and Application

The architecture of WSN is OSI module. From the [2], it shows that the system of the architecture include five layers and three intersecting layers. The five layers are the application layer, transport layer, network layer, data link layer and physical layer. The application layer is responsible for traffic management and provides software for the applications. These applications convert data to search for positive information. The transport layer has the ability to congestion avoidance, and it is important for the whole network to transport data. The main function of the network layer is selecting routing, which can make sure the transport is successful and punctual. The data link layer tries to establish data links between adjacent nodes, provide error-free transmission of data frames on the channel through error control, and perform action series on each circuit. Lastly, the physical layer specifies the mechanical, electrical, functional, and procedural characteristics of communications equipment for establishing, maintaining, and dismantling physical link connections.

In a WSN system, many sensor nodes are randomly deployed in or near the monitoring area and can form a network through self-organization. The data monitored by the sensor node is transmitted hop-by-hop along other sensor node, and the monitoring data may be processed by multiple nodes during transmission, routed to the aggregation node after multiple hops, and finally reached the management node through the internet or satellite. From [3], it shows that WSN nodes can sense physical parameters around the environment and transmit the collected information via a single-hop or multi-hop fashion through routing protocols and algorithms.

The application of WSN in the field of medical use, whether from a domestic or international point of view, is a general hot topic, and is a topic worth exploring. For medical aspects, the work is supposed to pay more attention to accurate and intelligent coverage. From this point of view, WSN is a great application prospect. WSN uses its own advantages, can be a real-time non-invasive collection of patient information, a variety of sensor nodes that can detect the patient's heart rate, blood pressure, and ECG real-time monitoring, to ensure the safety of patients. In some hospitals and medical colleges in China, this work has been carried out. disease prevention and daily health care have gradually become the main role of the global medical market, and the remote real-time monitoring of patients every single day has a great role in medical treatment. In recent years, Shanghai Medical University has published a list of telemedicine consultation experts online. In 2018, Matthew N.O. Sadiku, Kelechi G. Eze, and Sarhan M. Musa have researched WSN for Healthcare [4]. In ICACITE, Charanjeet Singh gives research on wireless sensors to the world of healthcare systems and sensor network-based medical imaging [5].

3. The energy consumption problem

Though WSN recently has been initially developed in the medical industry, there are still some problems that need to be solved. This article discusses the energy consumption of WSN in the medical industry. A WSN consists of hundreds or thousands of sensor nodes. These devices utilize limited power for data transmission, so the energy problem will be tricky. The collected data from the target environment is sent to that base station (BS). BS is a node that is interested in receiving data from asset of sensor nodes.

However, this method will result in high communication costs. From Mohamed Elshrkawey's opinion [6]. WSN suffers from extensive constraints such as limited memory, little computational ability and so on. The nodes should run without care for a long time. And, the requirements of the application will decide the energy consumption, also the nodes will always be deployed in a harsh environment where cannot always replace the device. In the medical industry, the sensor nodes move frequently, although there are some protocols that have advantages on energy consumption, the weight and size of the medical facility and the single node's power are limited, when the energy is depleted, the entire medical system will be paralyzed, and that will cause a big problem for both hospitals and patients, even possible to threaten the patients' life. So, when the work solves the problem, it can ensure the operation of the whole system and protect the life safety of patients. Furthermore, solving this problem will bring the whole system benefits that the system don't need to replace the sensor nodes frequently and will use them for a long time. Thus, the work needs energy-efficiency routing protocols and routing algorithms to solve the problem. This part is going to show three algorithms that try to solve this problem.

4. The solutions to energy consumption

4.1. EOMRC

Feng Jiang and Wu Chun-chun introduced the first algorithm, the muti-hop clustering routing algorithm which is based on energy consumption balance, named Multi-hop and Clustering Routing algorithm based on Energy Optimized (EOMRC) [7].

4.1.1. Temporary head cluster selection stage. In this stage, the new protocol is based on the LEACH routing algorithm but considers the relationship between single-node consumption and network consumption. Feng Jiang and Wu Chun-chun improved the T(n) algorithm. This will make the node which have the highest rest energy and exceed the average energy ratio to become the head cluster node. Which can balance energy consumption.

$$T(n) = \begin{cases} \frac{P}{1-P*(r \bmod (1/p))} \left[E_R + (r_n \text{div} \frac{1}{p})(1 - E_R) \right] & n \in G \\ 0 & \end{cases} \quad (1)$$

Else

$$E_R = \frac{E_{res} / E_{ini}}{\sum E_{res} / \sum E_{ini}} \quad (2)$$

E_{res} means the current remaining energy of the sensor node; E_{ini} means the initial energy value; R_n means the number of consecutive times that the node has not been elected as the cluster leader node number, once elected, R_n will rest to 0. $\sum E_{res}$ represents the sum of the remaining energy; $\sum E_{ini}$ represent the total initial energy of the remaining nodes in the network.

4.1.2. Formal head cluster node selection stage. This stage makes the ratio of the remaining energy of the node to the cost of intra-cluster communication the node's energy consumption ratio [7]. Reselect the official cluster head node in the already divided cluster. In each cluster, the nodes calculate the energy consumption ratio in the cluster and select the node that has the largest energy consumption ratio in the cluster to be the head node of the cluster. When selected to the head cluster node, the node will assign a fixed TDMA time slot to member nodes in this cluster. The member nodes will send monitoring data to the first node within their respective time slots.

4.1.3. Inter-cluster communication stage. In this stage, each node selects the head cluster with the largest weight as the next-hop node from the head clusters with a weight greater than 1 to form a multi-hop routing path. The node with the largest weight transmits the collected monitoring data to the base station, and if it is not found, the cluster head node will directly perform single-hop data transmission with the base station.

4.2. LEACH-improved algorithm

The second algorithm is presented by HUANG Li-xiao, Wang Hui, and their team they base on energy balance and high efficiency to improve LEACH protocol algorithm, called LEACH-improved algorithm [8]. LEACH protocol is that randomly choose the head cluster node in a circular manner and get the energy to distribute to each sensor node.

In this improved algorithm, they add three new factors: spacing factor, leftover energy factor, and density factor. Using the spacing factor, the farther the distance between the normal node and the sink, the weaker the signal received and the distance between the nodes. Because the energy that the head cluster node consumes is larger than that of other nodes, if the head cluster node is chosen frequently among normal nodes, it will deplete their energy, which can lead to the network signal transmission partial paralysis, so that HUANG uses the leftover factor. Using the density factor, this algorithm can know exactly the node quantity near the session.

The process of LEACH-improved algorithm:

- 1). At the initial stage, the sink will broadcast the signal.
- 2). Detect the nodes in the area by the strength of the received signal, according to equation 4), roughly calculate the distance between the nodes and sink node, and get the spacing factor.
- 3). Calculate the leftover factor.
- 4). Calculate the density factor through equation 6),7).
- 5). Based on the leftover energy, the distance between sink nodes and these nodes and the density calculate the threshold $T(n)$.
- 6). Randomly generates a number that is below zero. If the number is less than the $T(n)$, the node will be selected to the head cluster node.
- 7). The normal nodes choose whether to join clusters through the strength of the received signal.
- 8). At the initial stage, the leftover factor's weighted value get 2/5, the spacing factor's weighted value get 2/5, and the density factor's weighted value get 1/5.
- 9). If the energy of the 1/2 of the nodes is less than the original 1/2, the energy factor's weighted value will increase to 3/5, and the weighted value of the spacing factor will get to 1/5.
- 10). When modifying the value of each factor, cyclic data transmission.

4.3. GBSR

The third algorithm is produced by SONG Zichao, who bases it on the global balance strategy to produce a routing algorithm called GBSR [9]. Firstly, it follows the head cluster election based on regional division, the competitive radius is proportional to the distance between the belonging area to the sink node. Secondly, when applying the Dijkstra algorithm to find the optimal path between clusters, the EDDR algorithm uses the composite weights based on energy distance, but in practice, the transmission energy consumption and distance are nonlinear, so the algorithm uses the composite weights based on energy consumption and residua energy to further improve the energy equilibrium effect of the network.

4.3.1. *The election of the head cluster and the establishment of clusters.* GBSR's formula for calculating the head cluster competition radius:

$$R_{c,i} = \left(1 - c \frac{R_q - R_i}{R_q - R_1}\right) R_c^0 \quad (3)$$

The element in $\{R_1, R_2, \dots, R_q\}$ are ascending arrangements, R_q is the largest divided radius, R_1 is the divided radius for the minimum.

Within each area, nodes enter the head cluster candidates in order of energy from high to low, and the distance between the new candidate head cluster add all the head clusters that have been previously elected should be greater than their own competition radius.

4.3.2. *Inter-cluster routing.* ① The weight between the head clusters

The energy consumption of sending node factor:

$$F_k = E_{Tx} \quad (4)$$

E_{Tx} is the sending node energy consumption.

Receive node remaining energy factor:

$$F_R = E_0/E \quad (5)$$

E is the current energy, E_0 is the initial energy. The weight:

$$V = F_E/F_R \quad (6)$$

② The weight between the head clusters and Sink nodes

$$V = F_E = E_{Tx} \quad (7)$$

③ The weight between the Sink nodes and the head clusters

To find the data aggregation path from the head cluster to the sink node, there can be no sink node to cluster head loop, and the sink node to the cluster head is considered unreachable.

Inter-cluster routing is mainly to establish a least-cost aggregation tree from all head clusters to sink nodes.

5. Conclusion

This article mainly talks about the solution to the energy consumption problem which has in the medical field of WSN, and gives three algorithms for it. It is important to solve the problem of the energy consumption of the application of wireless sensor networks in the medical field. The medical industry needs many sensor nodes to monitor the patients' physiological parameters, environmental conditions, and the state of the medical device. However, the traditional WSN has challenges with energy consumption, which will limit its wide application in the medical field. From my perspective, first of all, the traditional WSN typically uses batteries as an energy source. However, battery life is limited and requires regular replacement, which not only increases costs but can also lead to disruption of the monitoring system. Therefore, reducing the energy consumption of wireless sensor networks is critical. The three algorithms used to solve this problem are very effective. When different kinds of factors to the algorithms, the algorithms will be more energy-saving. However, the algorithms still have disadvantages. The methods mainly monitor the leftover energy and optimize it. Though the life cycle of the network is extended, it does not essentially solve the problem of system energy consumption. From my point of view, the algorithms are supposed to decrease unnecessary calculations and communications and improve the sensor network routing algorithm. Also, it is important to optimize the network topology because of the environment. The sensor nodes are usually moving, so the reasonable layout of the sensor nodes is another way to improve energy consumption. In addition, data compression and aggregation techniques can also reduce the energy consumption of WSN. The sensor node can compress and aggregate the collected data to reduce the amount of data transmitted wirelessly. This not only reduces energy consumption but also reduces network congestion and transmission delay, and improves data transmission efficiency. Overall, the mission of improving energy consumption is still unfinished and has a long way to go, it is significant to improve this problem of WSN in the medical field which can benefit both the patients and hospitals. And, from my perspective, if the work solves this problem, it will be a great step for human life-saving and helping lots of people, it improves sustainability, monitoring, improves system efficiency, and drives innovation and development in medical technology, WSN applications in the medical industry will be more reliable, efficient and intelligent, providing better protection for the health of patients.

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