Highly Reliable Routing In Healthcare Systems Based on Internet of Things

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Abstract

Healthcare is an important application of Internet of things (IoT) and body sensor networks (BSNs). Known as a method of measuring and collecting data in healthcare applications, a BSN must provide more reliable routing. Therefore, it is necessary to develop a method for reducing communication rates and improving reliability in healthcare systems. This paper proposes a novel method for routing data packets to enhance reliability in IoT-based healthcare systems. Given the nature of healthcare systems and importance of energy consumption, the proposed method employs different criteria (residual energy and variance of distance from neighbours) to perform the routing process. The results of implementing the proposed method indicated its acceptable performance in comparison with LSR, OLSR, and MAEB protocols. The method also managed to achieve the goals of retaining the quality of packets received by the sink and reducing energy consumption in healthcare systems.

Introduction

Known as a promising scenario affecting human life, the Internet of things (IoT) can integrate modern technologies with the future life. The IoT has developed the concepts of the World Wide Web from a homogenous network which merely includes online computers to a network of heterogeneous equipment and devices such as home appliances, mobile electronic devices, and wireless sensor networks [1]. The IoT also facilitates the transition and reception of medical information. Compliance with the principles of primary healthcare can result in better outcomes, improve people's satisfaction, and reduce costs. However, an IoT-based healthcare system faces certain challenges such as the absence of necessary standards for healthcare in the IoT, collection of specific patient data, untimely presentation of stored patient data, and big data. The data should first be transferred to the target servers for processing. The data transfer operation from a source to a destination would require high reliability, an error-free procedure, and a delay-free transfer; these factors can transform routing [2]. Limitations and challenges of sensor networks, especially a BSN which is known as the most important subcategory of the IoT, distinguish them from other distributed systems. These limitations can also have certain effects on the design of wireless sensor networks (WSNs) including different protocols and algorithms classified as other categories of IoT. Hence, traffic models, energy efficiency, two-sided links, and radio transmitter usage rats pose some of the most important constraints on routing [3]. There are far more constraints than what has been mentioned; however, routing challenges are basically affected by the above-mentioned limitations in networks. This paper proposes a method for routing data packets in IoT-based healthcare systems in order to improve reliability.

The paper consists of the following sections. Section 2 reviews the related works, whereas Sect. 3 describes LSR, OLSR, and MAEB algorithms. The proposed method is presented in Sect. 4, and its simulation results are evaluated in Sect. 5. Finally, Sect. 6 draws a conclusion and introduces future works.

Related Works

In recent years, many routing algorithms have been proposed for IoT-based healthcare systems to seek specific goals. This section analyses some of the previous methods. In [4], an energy-efficient inference-congestion-aware routing technique called survivable path routing was proposed for sensor networks. To select the next-hop node, the proposed protocol benefits from a criterion that is a function of three factors, *i.e.* the ratio of signal to link noise and interference, survivability of path from the next-hop node to the destination, and the congestion level of the next-hop node. In [5], a novel protocol was proposed for the IP-based wireless sensor networks. It uses a combination of two routing criteria, *i.e.* link quality and residual energy status of a preferred parent, to select the optimal path. These two criteria were combined with each other based on the alpha weight. In [6], an efficient energy-aware multi-hop multi-channel routing scheme was proposed for peer-to-peer communications in the IoT. The proposed method creates a radio environment map through spectral sensors to record the use of a spatial-temporal spectrum. The radio environment map is also employed for multi-hop routing. It includes the best path, the best channels of every hop along the path, and the appropriate transmission power for every hop. In [7], a novel technique was proposed to improve the quality of routing in the IoT. In fact, the information of layer transfer is also expected to improve the network lifetime by considering information in years to greatly reduce the network energy consumption. In [8], a fuzzy probabilistic routing protocol was proposed to control path-requesting packet transmission in the IoT to prolong the network lifetime and reduce the packet loss rate. The fuzzy controller receives the input descriptors in routing criteria in order to optimise the network performance. In [9], a reliable oneM2M-based IoT system was proposed for personal hygienic devices. This paper also proposed a fault-tolerant algorithm for the IoT systems in which the gateways of related layers are connected to develop a change of fault tolerance at every level. In [10], the problem of vehicle routing was analysed in housing healthcare by employing the genetic algorithm for routing in the proposed method which aim to reduce delay and improve reliability in communication packet transmission. The paper proposed in [11] is a protocol inspired by artificial immune and energy-efficient clustering based on the adaptive fuzzy logic for the IoT systems through a wireless sensor network. The proposed method used an adaptive fuzzy multiple-criteria decision-making approach to select an appropriate cluster head. Moreover, the artificial immune optimisation algorithm was used in routing to improve reliability.

In conclusion, although many studies have analysed routing in IoT-based healthcare systems, there are only a few studies on reliability improvement, energy consumption reduction, and throughput enhancement. This paper proposes a novel approach to improve reliability in IoT-based healthcare systems by enhancing the related parameters.

Analysis Of Lsr, Olsr, And Maeb Algorithms

This section introduces three routing algorithms for wireless sensor networks. Integrating these algorithms, the proposed method changes the routing processes to develop a novel approach to reliable routing in IoT-based healthcare systems.

3.1. LSR Algorithm

In the link-state routing (LSR) algorithm [12], the source node multicasts patient information to all of its neighbours. Similarly, the nodes which receive the information multicast it to all of their neighbours so that the information will reach the access gateway. The disadvantages of LSR are congestion due to information multicast and increased energy consumption throughout the network.

3.2. OLSR Algorithm

The optimized link-state routing (OLSR) algorithm is an optimized version of LSR [13]. Similar to LSR, the source node in OLSR multicasts information, and the nodes existing on the MPR list of the source node are authorized to send information. Therefore, every node creates an MPR list. For this purpose, every node finds its single-hop and double-hop neighbours. The source node then selects a few single-hop nodes and adds them to the MPR list which is the only way of reaching a few double-hop nodes. When an MPR list is created for every node, the information transmission process is performed between nodes until the destination node is reached. Figure 1 demonstrates an example of the information transmission process in OLSR. In this figure, B and D nodes are placed on the MPR list because they are the only ways of achieving H, J, E, and F nodes.

3.3. MAEB Algorithm

In the maximum allowable number of error burst (MAEB) algorithm, the source node first calculates an equation for every neighbour and then selects a node with a smaller value of the equation as the next hop for information transmission [14]. The process of calculating *k* nodes in the MAEB algorithm is as follows:

$$\mathrm{K} = a\frac{D_N}{D_S} + b\frac{V_N}{V_S} + c\frac{E_T}{E_R} \qquad (1)$$

In the above equation, constant coefficients are shown by *a*, *b*, and *c*, whereas D_N denotes a neighbour's distance to the access gateway, and D_S refers to the distance between the source node and the access gateway. Moreover, V_N indicates the neighbour's velocity, and V_S refers to the node's velocity, whereas E_T shows the energy required for transmission, and E_R means the residual energy. Therefore, the equation is calculated for every neighbouring node. A node with a smaller *k* is selected to receive information packets from the source node.

The Proposed Method

A hybrid of OLSR and MAEB algorithms, the proposed method consists of two phases. In the first phase, *k* is calculated for every neighbour, and every node with a larger *k* is added to the MPR list in the second phase to perform the information transmission process based on the existing list. In the proposed method, the network environment includes a few patients as noes. A few body sensors are also installed on each patient. In the general routing process, the source node is selected as a patient's sink node which receives the information from body sensors and must send the sensed information to the access gateway with high reliability (*i.e.* a low packet loss rate and high throughput). Figure 2 shows the general model of the proposed method through an example of the information transmission process between the source node and the access gateway.

4.1. Calculating Equation *K*

The first phase resembles the MAEB algorithm; however, a larger *K* is selected. A few parameters (distance, total residual energy, number of neighbours, and variance of distance) are also considered in equation *K* as below:

$$K = A \times \frac{B \times C \times D}{V} \quad (2)$$

In the above equation, *A* denotes the distance from the nearest MPR member, whereas *B* refers to the total residual energy of neighbours around a neighbouring node, and *C* indicates a neighbouring node's residual energy. Moreover, *D* shows the number of neighbouring nodes, whereas *V* denotes the variance of distance to the neighbours covered by the neighbouring node.

4.2. MPR List and Information Transmission

In the second phase, the neighbouring node is added to the MPR list with a larger *K*; therefore, a few neighbouring nodes are added to the MPR list based on *K* in the proposed method for information transmission. After that, the information is sent to the designated nodes of the MPR list. In other words, the source node obtains the list of single-hop and multi-hop neighbours and then selects a few single-hop nodes and adds them to the MPR list. They are the only way of reaching a few double-hop nodes. After the MPR list is created (through equation *K*), the destination node multicasts the information, and only the MPR nodes can then multicast the information. As discussed earlier, equation *K* is calculated for each neighbour of the source node, and a node with a larger *K* is added to the source node's MPR list. This process lasts until the information reaches the base station.

Evaluation Of Simulation Results

The proposed method was simulated in MATLAB 2019, and the results were evaluated by using such criteria as the total consumed energy, residual energy, throughput, and total packet loss rate of the network. The proposed method was then compared with LSR, OLSR, and MAEB protocols. Table 1 presents the simulation parameters. According to the results, the proposed method outperformed the other protocols and also yielded a higher reliability.

Table 1 Simulation parameters

Parameter	Test
Number of patients	20
Network environment dimensions	1000*1000 cm^2
Packet size	500 bytes
Number of rounds	1000
Sensor information transmission rate	3 s

Figure 4 illustrates the results of comparing the proposed method with the other protocols in the total packet loss rate. In the network environment, the more successfully the packets are sent among nodes, the lower the packet loss rate. According to the results, the total packet loss rate was lower in the proposed method than in other protocols. In other words, increasing the rounds increased the packet loss rate more in other protocols than in the proposed method. This parameter grew considerably in LSR. Packets are lost in the network when one or more sent packets fail to reach the destination node for any reason.

Figure 5 demonstrates the results of comparing the proposed method with the other protocols in the total consumed energy. According to the results, the proposed method consumed less energy than the other protocols, for it is efficient in selecting energy-aware paths between the sensor node and the sink in addition to considering the energy levels of double-hop neighbouring nodes. Therefore, it can be stated that the proposed method yielded high efficiency with the least energy consumption.

Residual energy indicates how much energy the nodes have to send information to the sink node. Figure 6 depicts a comparison between the proposed method and the other protocols in residual energy. The LSR, OLSR, and MAEB protocols lost more energy than the proposed protocol at first due to the computational load of the path discovery process and information transmission among nodes. However, the proposed method consumed less energy because all of its sensors were alive and only needed to calculate the energy levels of their double-hop neighbouring nodes. Another reason for the high levels of residual energy in the proposed method was that the neighbouring nodes' energy was used as a criterion for selecting the MPR list.

Throughput can be used as a criterion for calculating the network lifetime, especially in a BSN. Different definitions of throughput have been given by different studies. Throughput is a measurable criterion in BSNs. It expresses the extent to which data are provided for transmission to the sink. In other words, throughput indicates the number of packets entering the sink per millisecond. Figure 7 draws a comparison with the proposed method and the other protocols in total throughput. Accordingly, as the rounds increased along the network execution, total throughput increased in the proposed method and the other protocols. In other words, increasing the rounds had no significant negative effect on the throughput of the proposed method. As the number of noes increased to select the right path, more data were transmitted in the network. This can reduce throughput in a BSN environment.

Conclusion

This paper proposed a method for routing information packets in order to improve reliability in IoT-based healthcare systems. The proposed method was simulated in MATLAB 2019, and it was then compared with LSR, OLSR, and MAEB protocols in performance. According to the evaluation results, the proposed method managed to achieve the expected goals, *i.e.* improving reliability and reducing communication rates of sensor network nodes. Furthermore, comparing the results of the proposed method with those of the other protocols indicated that it prolonged the network lifetime and reduce energy consumption in addition to improving total packet loss rate, total residual energy, and total throughput. Based on the literature, the use of efficient routing for decreasing packet loss rate and increasing reliability in healthcare can always have a direct effect on the system lifetime. It is also necessary to employ effective techniques such as node clustering to achieve the abovementioned goals. Future studies can implement the proposed method through energy-aware clustering. For this purpose, a fitness function can be employed by considering metaheuristic algorithms to select appropriate nodes as cluster heads with higher levels of residual energy than all of the existing nodes in a network in order to improve the network reliability.

Declarations

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Availability of data and material (data transparency): Not applicable.

Code availability: The code of this manuscript is available.

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Figures

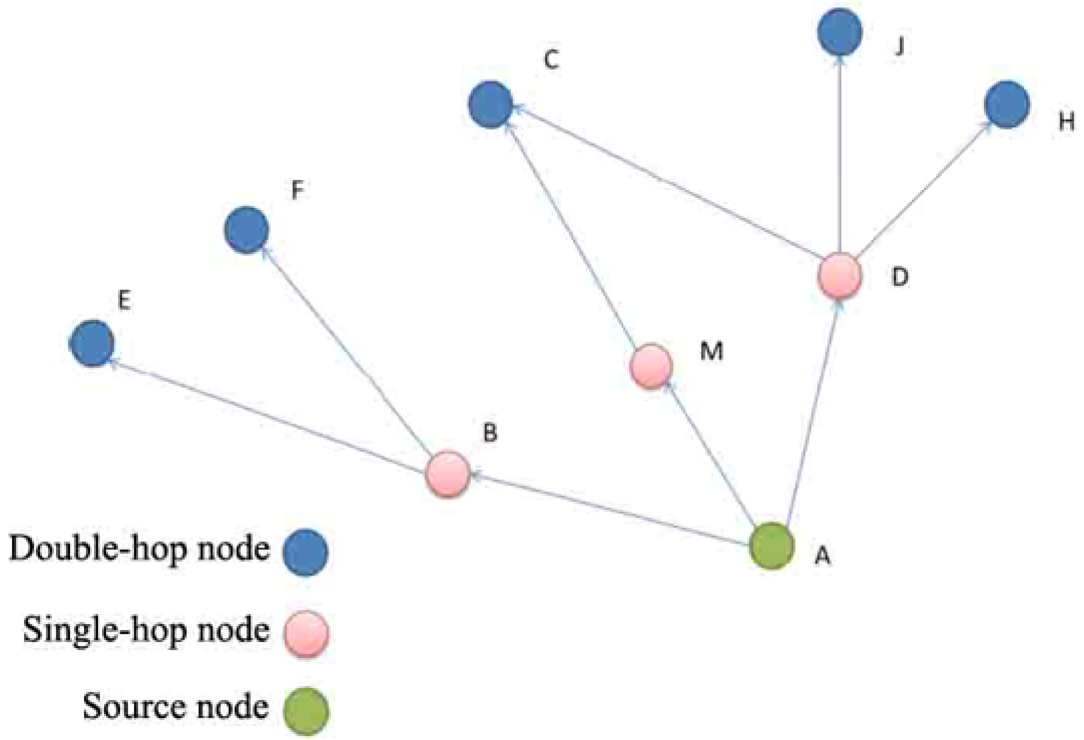

Figure 1

Information transmission process in OLSR

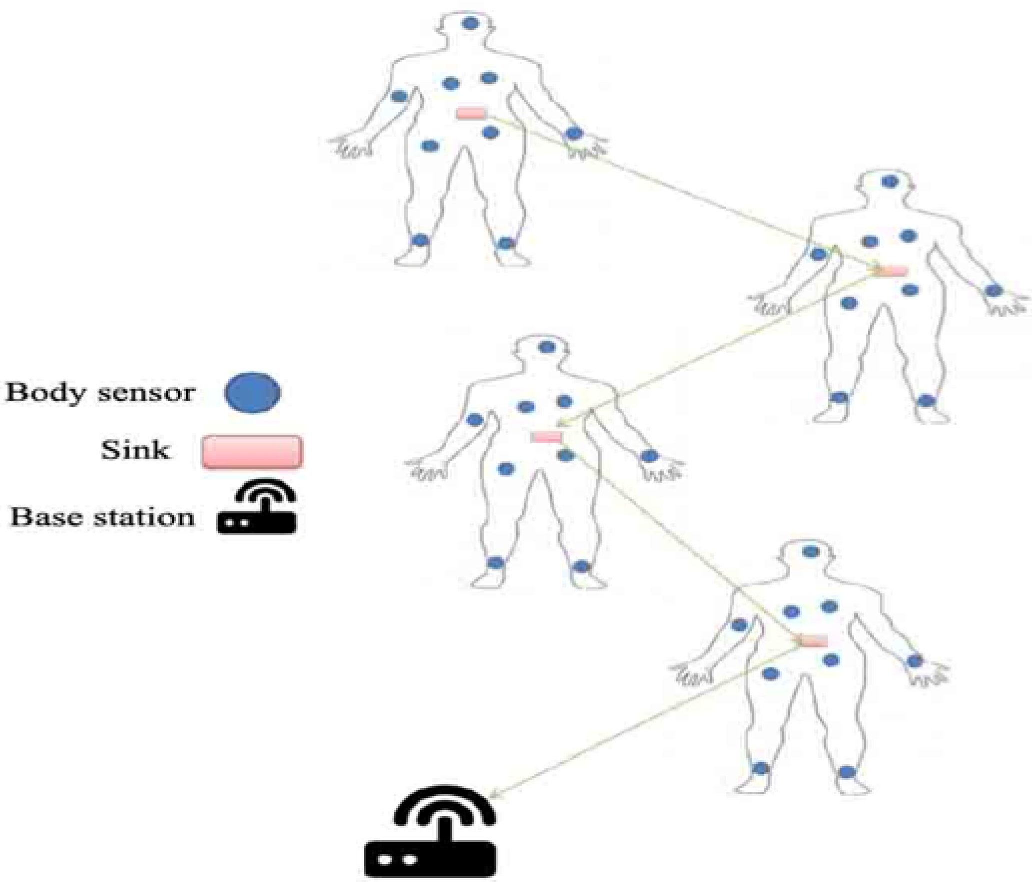

Figure 2

Network environment in the proposed method

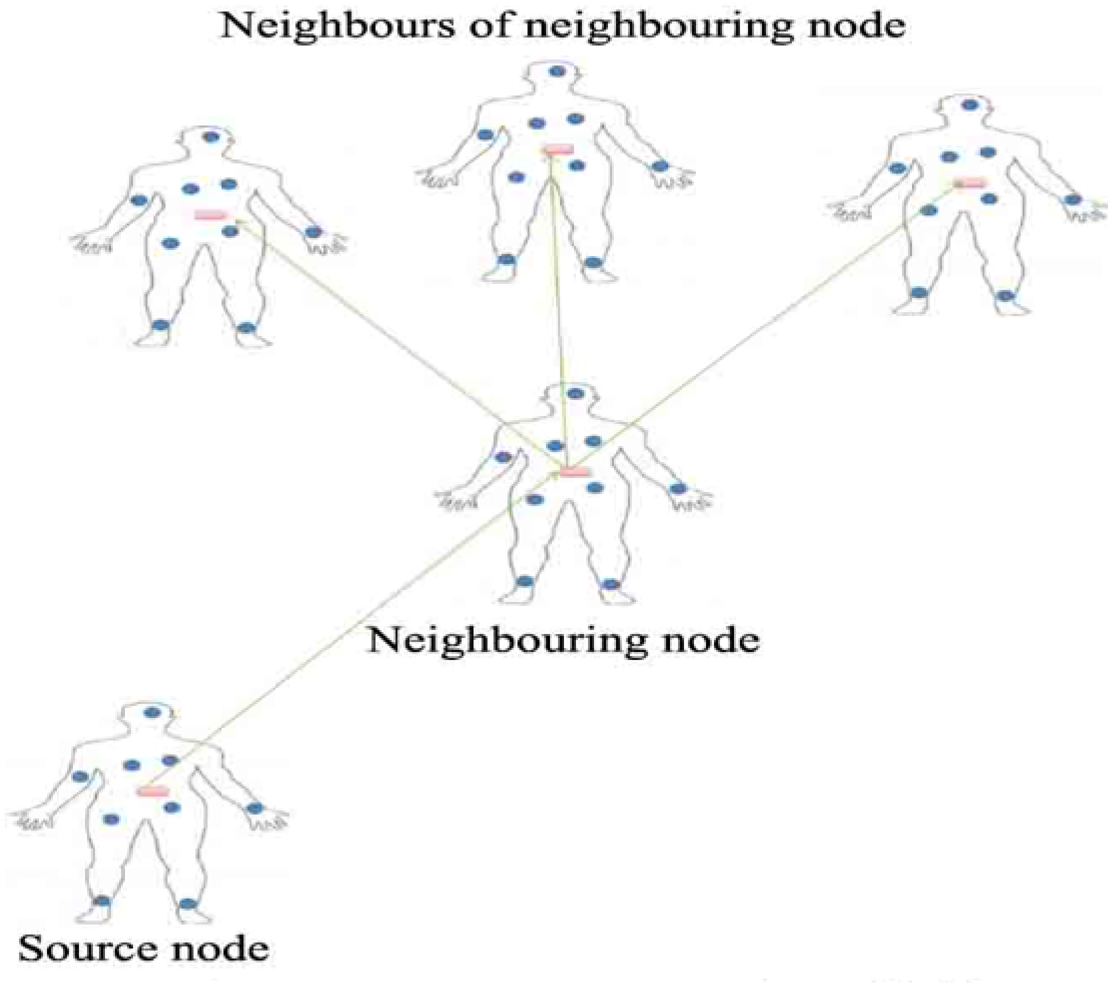

Figure 3

Neighbours covered by the source node’s neighbouring node

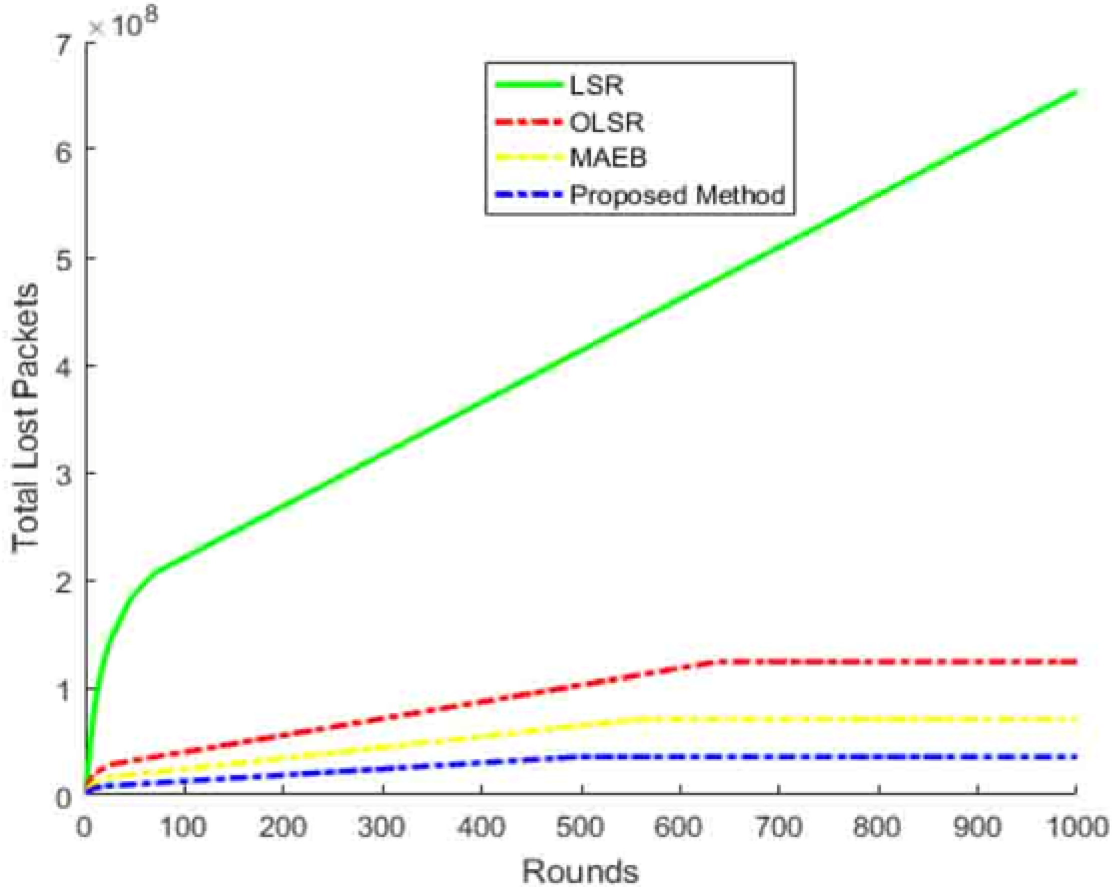

Figure 4

Comparing the proposed method with the other protocols in total packet loss rate

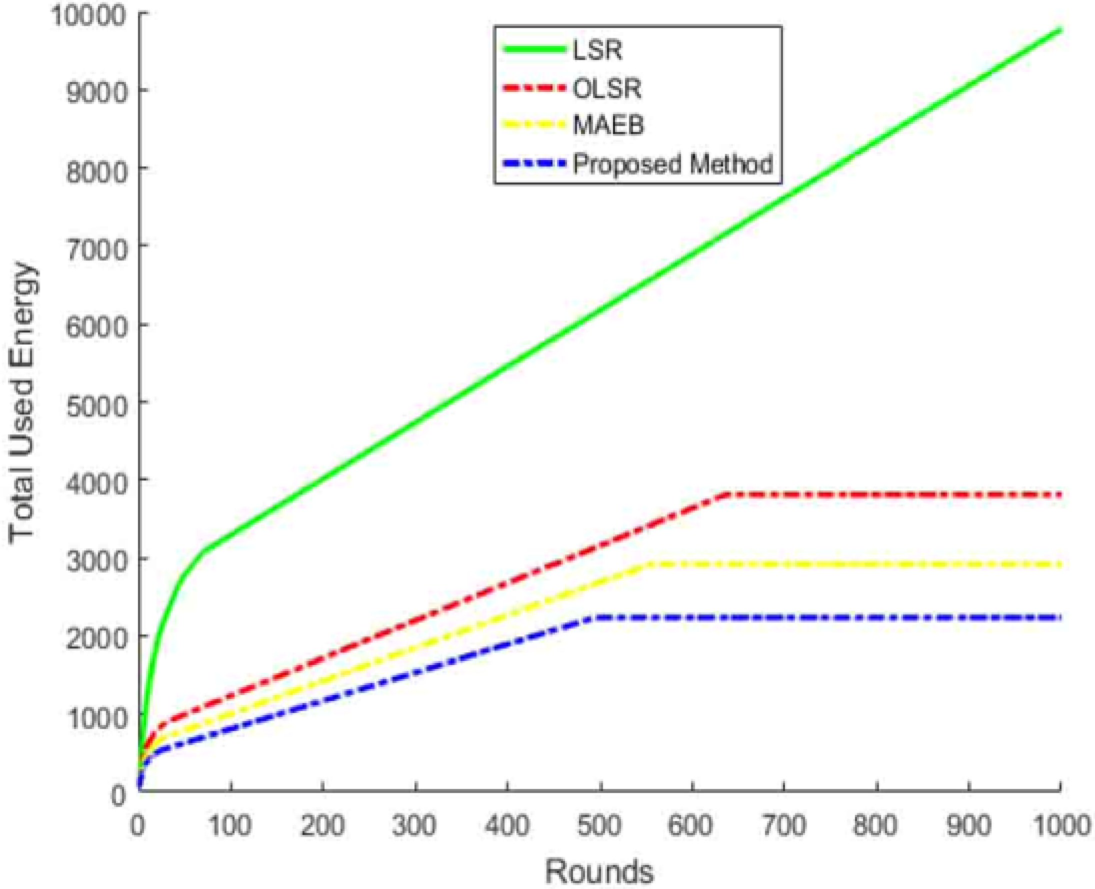

Figure 5

Comparing the proposed method with the other protocols in the used energy

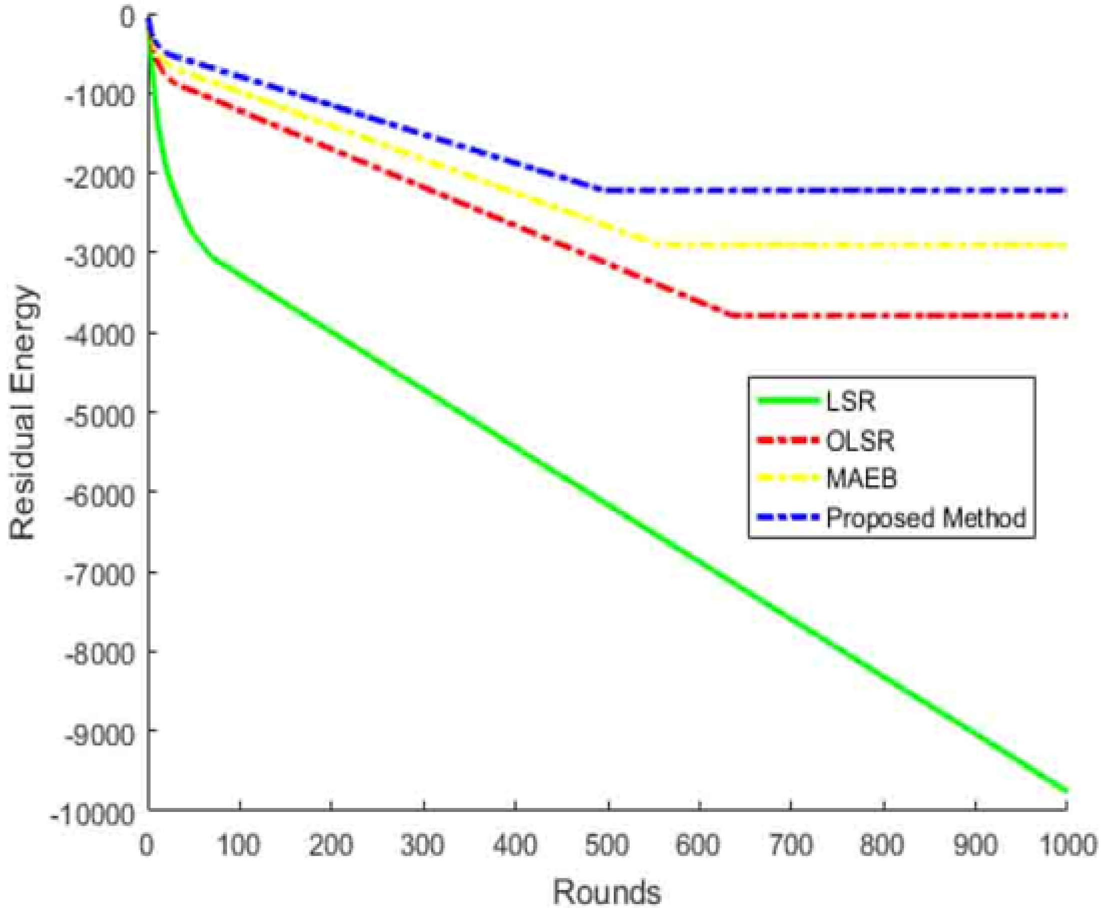

Figure 6

Comparing the proposed method with the other protocols in residual energy

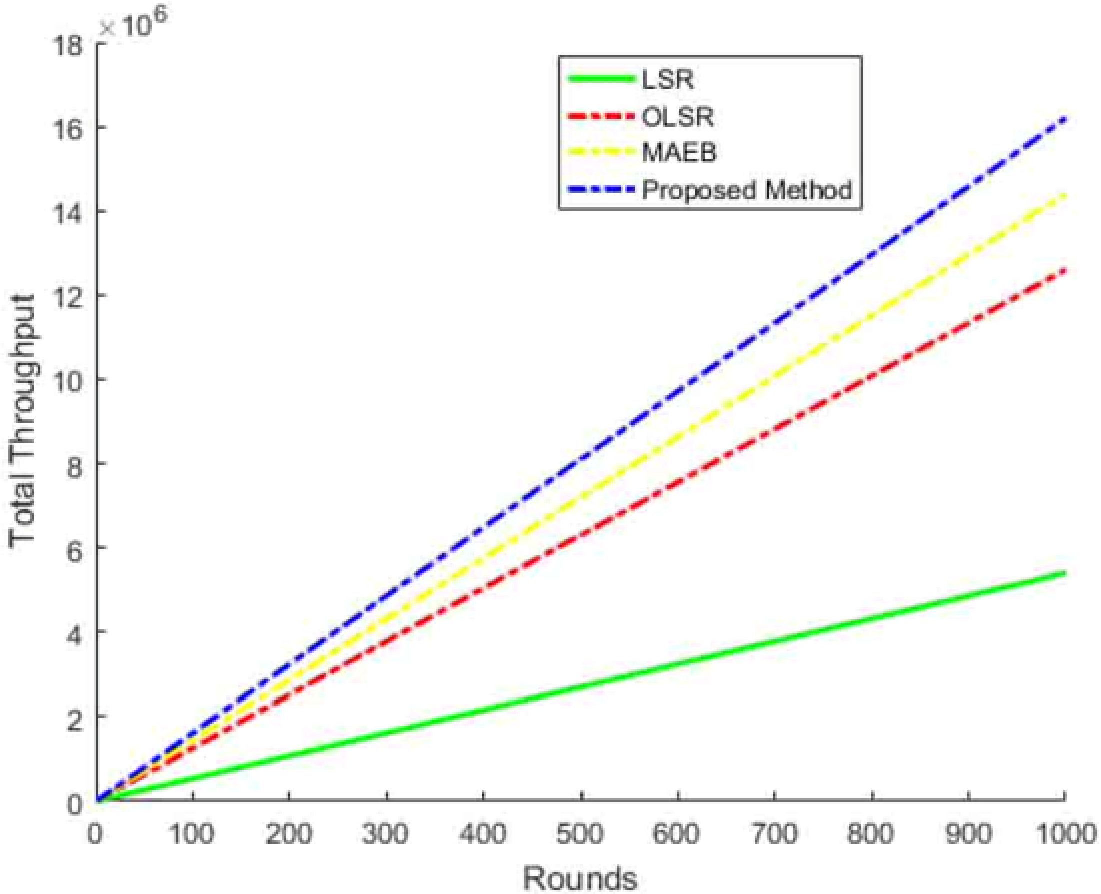

Figure 7

Comparing the proposed method with the other protocols in total throughput