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Application of Internet of Things in the Health Sector: Toward Minimizing Energy Consumption

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Abstract: The Internet of Things (IoT) is currently reflected in the increase in the number of connected objects, that is, devices with their own identity and computing and communication capacities. IoT is recognized as one of the most critical areas for future technologies, gaining worldwide attention. It applies to many areas, where it has achieved success, such as healthcare, where a patient is monitored using nodes and lightweight sensors. However, the powerful functions of IoT in the medical field are based on communication, analysis, processing, and management of data autonomously without any manual intervention, which presents many difficulties, such as energy consumption. However, these issues significantly slow down the development and rapid deployment of this technology. The main causes of wasted energy from connected objects include collisions that occur when two or more nodes send data simultaneously and the leading cause of data retransmission that occurs when a collision occurs or when data are not received correctly due to channel fading. The distance between nodes is one of the factors influencing energy consumption. In this article, we have proposed direct communication between nodes to avoid collision domains, which will help reduce data retransmission. The results show that the distribution can ensure the performance of the system under general conditions compared to the centralization and to the existing works.

Key words: Internet of Things (IoT); energy consumption; cloud computing; data storage

1 Introduction

In recent years, the Internet of Things (IoTs) has been one of the most powerful technologies that have advanced today's computing power[1]. IoT has guaranteed standards of reliability and communication. In the IoT environment, all objects are linked to the Internet because of their processing, computing, and communication capabilities. IoT has changed the design of Internet networks, making them universal. It allows communication between several types of objects following the all-in-one standard[2,3]. This technology represents several objects in the form of a dedicated and easy-to-use device that can communicate on several types of wireless networks. Suddenly, connected objects have changed several research areas, making them more creative, such as the medical field. In the medical field, IoT uses several types of sensors that act as nodes to receive data. These sensors are inexpensive, implanted, and portable, allowing people to benefit from existing

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medical services at any time and in any place and to have a good follow-up on their health[4, 5]. In this paper, we have proposed a new solution to the application of IoT in the medical field, which consists of three steps detailed in Fig. 1. Our architecture is explained as follows:

Step 1: Nodes are placed on the patient's body. These sensors collect data from the human body to determine the state of the body. The data collected using these nodes are sent to the main node following the IEEE 802.15 standard[6].

Step 2: This step is the intermediary between Step 1 and Step 3. In this part, we will use one of the modes of communication to accomplish our goal. The data collected in the previous step will be sent to the next step to be processed, stored, and predicted.

Step 3: The data collected by Step 1 and transferred to Step 2 are stored in this step to be analyzed to help us make decisions.

In this work, we improve the use of IoT in the medical field in Step 1, which will be detailed later in Section 3. The nodes in the architecture use a wireless communication method to exchange data. The human body could disrupt the transfer of data between nodes, which should be taken into account in our solution (Step 1).

In addition, the need for efficient power consumption must be addressed by power control solutions due to repeated battery replacement, which is a very difficult job for the implanted sensor node[7, 8]. Among the solutions adapted to meet the challenges of IoT using the physical layer, many techniques can improve network performance, such as channel coding, network coding, modulations, and flows[9–11]. In our article, we are interested in flow management. We can achieve the latter owing to distributed communication.

The rest of this article is organized as follows: We present some related works in Section 2, the model and architecture of the system, as well as the proposed new architecture, are presented in Section 3. Section 4 presents the new routing algorithm. In Section 5, a general architecture of the system was proposed with the results and discussion. Finally, Section 6 concludes our article.

2 Literature Review

So far, a lot of researches have been conducted on reducing the energy consumption of IoT devices. Reference [12] studied a solution, which verifies the power consumption and allocation of blocks. Reference [13] attempted to increase the capacity of wireless body sensor network technologies. Reference [14] implemented a cognitive radio-based architecture for a medical BAN. The solution adopted is based on the adaptation of the 802.15.6 IEEE. Reference [15] used two architectures of cognitive radio, with one based on the reduction of electromagnetic interference. A simplified human body system was proposed[16] to detect radio channels in BSN. This proposed solution aims to use the measurements of CR parameters. Reference [17] proposed a solution composed of three levels. The first phase is the use of a BSN, the UWB is the technology used in this solution. The constitution of the next level of the solution is

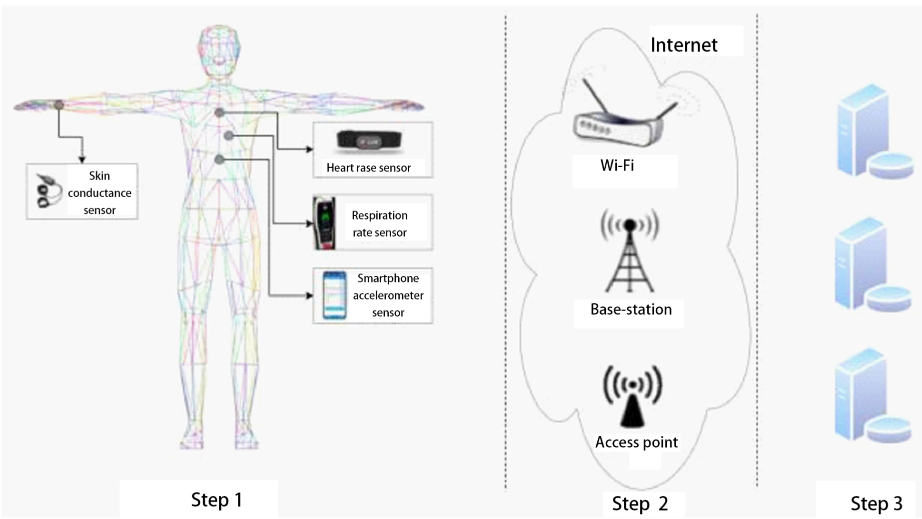

Fig. 1 Application of IoT in the medical field.

introduced by the CR controller. The last phase of the solution is the link between the two entities (vehicle and hospital). Reference [18] presented a solution that relies on the management of IoT flows. This architecture focuses on the centralization of flows, so that nodes send their data to the base. Reference [19] set up a description on the CRBSN for managing medical applications. A description of the wireless body network device systems has been provided. Thus, they studied MAC methods used for energy efficiency. To solve the problems described above and facilitate communication between different nodes, we have proposed a distributed architecture with a routing algorithm. The contributions of this work are summarized as follows:

(1) We offer two architectures: the first with centralized communication and the second with distributed communication, to demonstrate the role of flow distribution compared to the traditional solution.

(2) In addition, we have implemented our solutions in the medical field precisely on a human body.

(3) The proposed protocol aims to route data sent by nodes to determine the shortest path.

3 Network Architecture

3.1 Architecture designs

The first network architecture is a traditional solution (Fig. 2). This solution distributes nodes centrally on the architecture to collect data, and each node collects and transmits the data to the base. Thus, this solution is a single-hop topology that will allow nodes to send the collected data to the base. The base transmits what has been received via a wireless network. It is necessary to consider the number of nodes used and the distance between the nodes and base to establish this solution. The overload of the requests of the nodes toward the base can lead to collisions on one hand. On the other hand, distances between the nodes and base are variables.

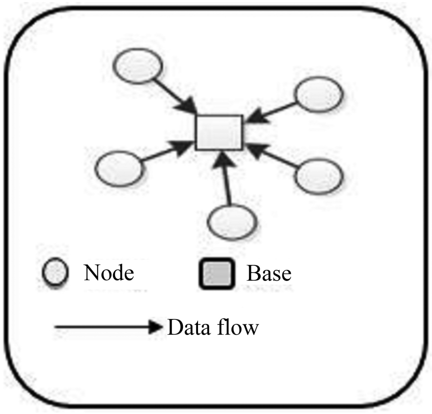

Fig. 2 Centralized collection.

Therefore, several nodes can be far from the base. Therefore, it is difficult to provide data appropriately to the base directly.

In Fig. 3, a new architecture is designed. The role of our solution is to connect the nodes to avoid overloading the base and avoid collision domains. Data sent are collected in a hierarchical fashion, where each node sends the data to the nearest node to the base.

3.2 Architecture implementation

In the architecture of Fig. 4, several sensors are distributed evenly over the human body for data collection. Each sensor collects a set of information and transfers it to the base. Nodes are fixed on the human body, named (N1; N2). The base outside the body functions as an information collection point that receives information from node N1. Thus, it plays a monitoring role. Due to the mobility of nodes on the

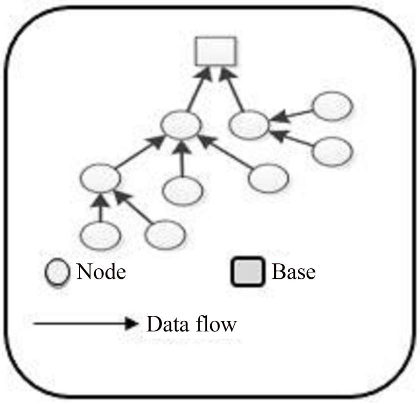

Fig. 3 Distributed collection.

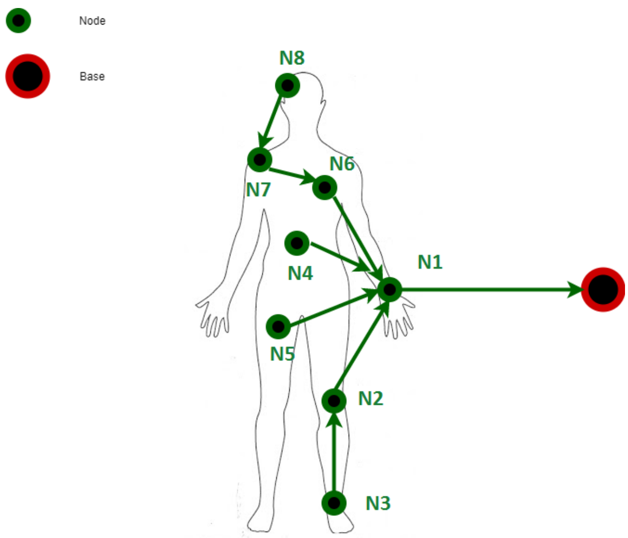

Fig. 4 Distributed collection of nodes on the human body.

body, the distances between the sensors (N1; N 2) and the base change, where several nodes can be located at a significant distance or else at a short distance, which makes the dimension of distances to be our main problem to be solved.

Thus, several sensors may have better channel quality than others compared to the base.

For example, in our case, the first node will transmit these data to the node closest to it, the latter will transmit the data of the first node, and these data are specific to the base. Through this way, we could establish a single connection with as much information as possible. The problem with transmitting data between nodes is that a single bit sent can consume as much as the execution of a thousand instructions by the processor. To reduce energy consumption, we have used multi-hop technology, so that each node can serve as an intermediary (the routing role) for other nodes, self-organizing to build a route through which the traffic passes messages.

The new network architecture can significantly displace the process of returning sensors to the base compared to traditional communication. Thus, new architectures could reduce delays and conflicts between sensors, which could lead to better energy savings.

4 Data Routing Algorithm

4.1 Proposed routing formulation

In our network architecture, we attempt to move from one node to another, and it is obvious to look for the shortest path to reach the node, that is, nodes with the shortest distance[20, 21]. If the number of possible paths between the starting node and the destination node is small, it will suffice to calculate the distances of paths between the nodes by adding the length of the links, which compose it, and to directly compare the lengths obtained. However, a solution becomes impractical if the number of nodes is very large[22, 23].

A vertex x is said to be visited if at least one path from A to x has been evaluated. A visited vertex has provisional $m(x)$ is the minimum value of the paths from A to x already evaluated, and $p(x)$ the corresponding predecessor[24].

A vertex is said to be calculated if it is visited and if we know that its $m(x)$, $p(x)$ values are final.

Initially, of course, the vertex A is calculated with $m(A) = 0$, $p(A)$ undefined since A is the starting point of the paths, and each successor x of A is visited, Then

$$M(x) = v(A, x), p(x) = A \tag{1}$$

The principle of exploration from the best consists in finding, among the visited vertices not yet calculated, a vertex whose value $m(x)$ is minimum. We can then show that, for such a vertex, the provisional values $m(x)$, $p(x)$ are final. This demonstration explicitly uses the fact that the values are non-negative.

We therefore mark x as calculated and we extend the exploration by examining each of the successors of x: each successor y not yet visited becomes visited. With

$$M(y) = m(x) + v(y, x), p(y) = x \tag{2}$$

While for each successor already visited, we update

$$M(y) = \min(m(y), m(x) + v(x, y)) \tag{3}$$

and

$$P(y) = p(x) \text{ if } m(y) \text{ is updated} \tag{4}$$

$M(y) = \min(m(y), m(x) + v(x, y))$(and $p(y) = p(x)$ if $m(y)$ is updated.

The exploration stops when all the visited vertices are calculated (the unvisited vertices are inaccessible, we can consider that they have a value of $m(x) = \infty$).

4.2 Application of the protocol

In this section, a model of links between nodes and the base in Fig. 4 is provided using the Dijkstra Algorithm to determine a shorter path to get to the point of arrival (the base). In Fig. 5, each node is represented by letters, for example, Node A and Node B. Flows are determined by distances. For example, the distance between Nodes A and B on the human body, and they are located 85 cm apart. These measurements are taken randomly to determine the path of the nodes.

The algorithm takes as input a directed graph weighted by positive reals and a source vertex. This involves progressively building a subgraph in which various vertices are classified in increasing order of their

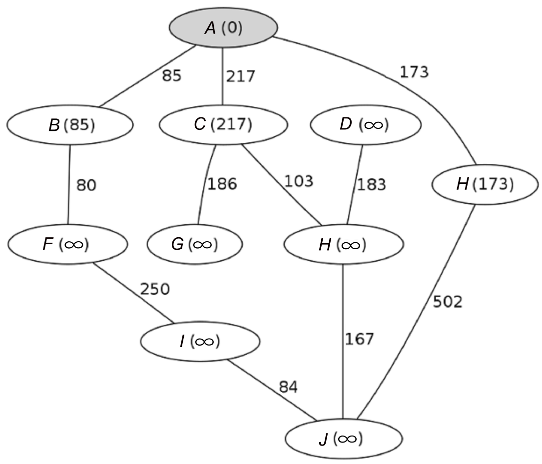

Fig. 5 Routing algorithm of initial state, the unit is cm.

minimum distance from the starting vertex. The distance corresponds to the sum of the weights of the borrowed arcs in Fig. 5. Initially, we consider that distances from each vertex to the starting vertex are infinite, except for the starting vertex for which the distance is zero. The starting subgraph is the empty set. During each iteration, we choose from outside the subgraph a vertex with the minimum distance and add it to Table 1 subgraph. Then, we update the distances of the neighboring vertices of the added one. The update is performed as follows: the new distance from the neighboring vertex is the minimum between the existing distance and that is obtained by adding the weight of the arc between neighboring vertices and vertices added to the distance from the added vertex.

Each step in Table 1 corresponds to a row. A line represents the current distances of the vertices from the starting vertex. A column represents the evolution of the distances of a given vertex from the starting vertex during the algorithm. The distance from a chosen vertex is underlined. Updated distances are crossed out if they are greater than distances already calculated. Table 1 gives not only the minimum distance between nodes, but also the backward path ($JHCA$) to go from A to J as well as all minimum distances from node A to the other nodes arranged by ascending order. The result of routing nodes (Fig. 6) is shown in the shortest path from A to J,

$$A > C > H > J \tag{5}$$

5 Simulation and Discussion

In our simulation, nodes and users are located in the same area, which will not exceed an area of 200 cm^2 to avoid collision and increased energy consumption. The base is located outside the human body hierarchically linked with the nodes of the body. Figure 7 shows energy consumption as a function of the distance between nodes.

In our simulation of Fig. 7, we have demonstrated with four axes of the solution the impact of distance on energy consumption. T1 axis consumes a large amount of energy because distances between the nodes of T1 increase, with sensors in a human body having more disturbance than in other places. T4 is the axis, which consumes the least energy compared to the other axes, which consume more energy.

The results show that energy consumption depends on the distance between nodes. However, it can be reduced

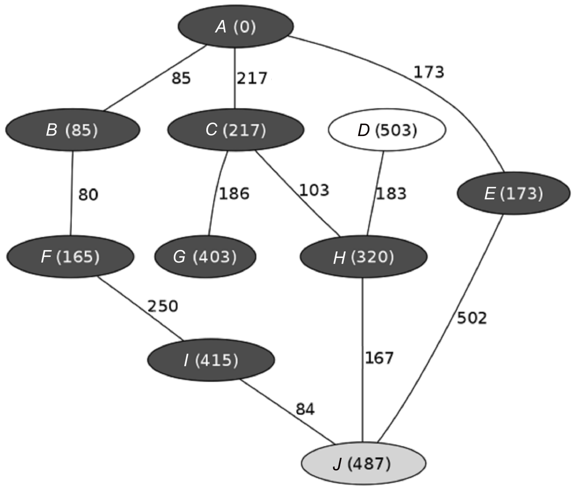

Fig. 6 Final state of routing algorithm, the unit is cm.

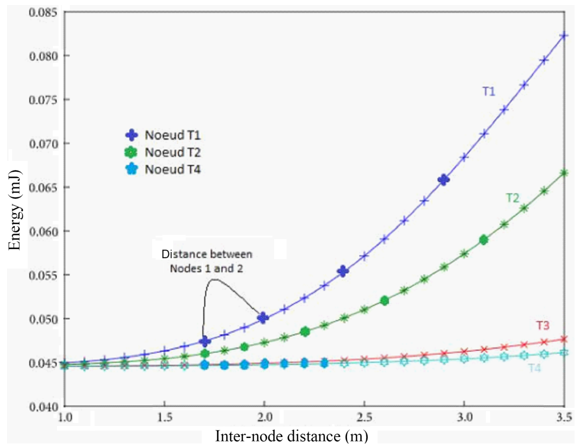

Fig. 7 Energy consumption as a function of the distance between nodes.

Table 1 Description of routing algorithm.

Heading level	A	B	C	D	E	F	G	H	I	J
Initial step	0	1	1	1	1	1	1	1	1	1
A (0)	—	85	217	1	173	1	1	1	1	1
B (85A)	—	—	217	1	173	165	1	1	1	1
F (165B)	—	—	217	1	173	—	1	1	415	1
E (173A)	—	—	217	1	—	—	1	1	415	675
C (217A)	—	—	—	1	—	—	403	320	415	675
H (320C)	—	—	—	503	—	—	403	—	415	487
G (403C)	—	—	—	503	—	—	—	—	415	487

by reducing the distances between nodes. In addition, the results show the contribution of our approach to reducing energy consumption of IoT devices.

6 Conclusion

In this article, a new architecture solution with a node routing algorithm is proposed taking into account the type of data collected. The proposed algorithm is based on the IEEE 802.15.6 CSMA policy and Dijkstra's theorem. The objective of the proposed solution can be summarized as follows: first, reduce the retransmission process and collisions by using a distributed architecture. Second, decrease the query overhead on the base, and third, use Dijkstra's algorithm to determine the shortest path. The proposed solution made it possible to obtain a better transmission quality of critical data. In addition, it could significantly reduce the probability of failure and power consumption.

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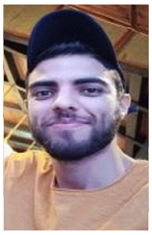

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