An Reliable Transmission Scheme Based on Opportunistic Cooperation for Wireless Body Sensor Networks

Dai Xuebing [1], Zhang Yan [2], and Wang Chaojing [3]
1. The Management Office of the Software System, Qingdao Electric Government Information Office, Qingdao Shandong 266071, China
2. Qingdao Electric Government Information Office, Qingdao Shandong 266071, China
3. Information Resources Management, Qingdao Electric Government Information Office, Qingdao Shandong 266071, China

Abstract—**Reliable data transmission of wireless body sensor networks with high quality of service requirement has been producing a new challenge. Considering the randomness and network dynamic condition, as well as restriction of system resources. In our paper, the network state information arrays of distance and channel quality were researched at first. Then the complete binay tree of network state and heap initialization were implemented. The optimal relay nodes were selected by heap sort approach. The data transmission scheme of reliable opportunistic cooperation was presented finally. The results of mathematics and simulation make clear that the proposed scheme have higher priority than the traditional transmission schemes in the matter of reliability, real time performance, energy efficiency and lifetime.**

Index Terms—**Wireless Body Sensor Networks; Relay Selection; Opportunistic Cooperation; Reliable Transmission**

I. Introduction

As technology and industrialization of developing, in productive labor due to the use or in contact with production of toxic chemicals, dust aerosol, abnormal weather conditions, high and low air pressure, noise, vibration, microwave, X-ray, gamma rays, bacteria dust exposure, mold; as well as long-term operating force posture, local tissue organ continuing pressure, etc., will impact staff's health significantly caused by the influence of different level, which need the real time monitoring and early warning [1, 2]. At the same time, with the development of the society, the ageing problem in today's world has become increasingly serious, how to effectively monitor real-time aging population health, become a global issue [3, 4].

In order to resolve the above problems, wirless body sensor network is widely used and researched, which is a special kind of wireless sensor networks [5, 6]. In this sensor network, each node attached biological sensors or medical devices with sensing unit, near the focus on the human body, its coverage is less than the wireless local area network and zigbee. The wireless body sensor network is formed using the placement on the human body or embedded in the body's physiological information [7], which is illustrated in Figure 1.

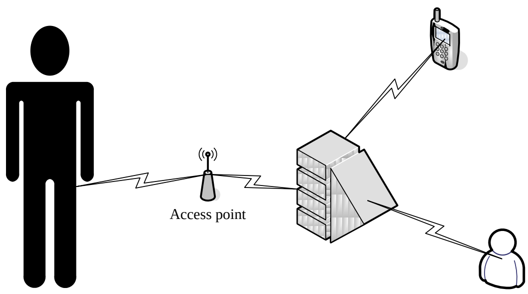

Figure 1. Wireless body sensor network

For dealing with the important issues such as body sensor network architecture design and implementation, multiple access control protocol design and implementation, energy saving control algrorithm, medical applications, healthcare applications, body channel communication scheme and so on. There are many research achievements, which are mainly about the above issues.

Yoo, J. et.al [8] implemented the wireless body sensor networks with both the sensor and the health monitoring band, which are using P-FCB for improving the wearability and production cost, as well as the sensor and network adapter chip, which hold 4.8 and 15.0 respectively. The four-levels hierarchical wireless body sensor network is designed and implemented in article [9], which is used to providing the gurantee for biometrics and healthcare applications. The network design separates pathways to improve the transmission performance and creates the communication cycle, which is presented to synchronize the network system with the pipeline. In article [10], the reliable adaptive relay selection scheme and adaptive QoS supported algorithm was presented for surpporting reliable relay selection. Qiang Fang et.al [11] describes a new wireless implantable body sensor networks, which is able to implement in wireless body communication and satisfy the quality of service and innovatively combination both sensing and actuation

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nodes to make a closed-control loop for physiological monitoring and drug delivery. Xiyu Lu et.al [12] proposed the plane for data controlling multiple with physical layer and MAC layer based on energy consumption and data sending rate.

From what has been discussed above, it is important to research and project the relay selection approach and opportunistic communication scheme to gurantee robust communication for wireless body sensor networks.

On the basis of existing research results, we research and create the reliable transmission mechanism based on cooperative communication and opportunistic approach, which consider the state of wirless body sensor network such as channel qulity or distance, using the opportunistic cooperative technology and select the optimal relay sensor nodes based on heap sort algorithm or complete binary tree for enchance the overall performance of wireless body sensor networks.

The rest of the paper is organized as follows. Section 2 describes the system models and state collection method of channel quality or distance. Section 3 proposes the heap sort struct and relay selection approach based on reliable opportunistic mechanism (OCTS). Section 4 shows the experiment results. Section 5 gives the conclution of this work.

II. SYSTEM MODEL

A. Network Model

In our wireless body sensor network model, the path loss based on free space propagation model, and combining the logarithm model and lognormal shadow model, so that we are able to be more approximate to the actual coverage, deployment, and topology control of wireless body sensor network.

In this model, considering the waves in the shining, no fading, the free space propagation of time-invariant, when the launch point D is greater than or equal to close to the distance reference D_0, the receiving power can be expressed as following formula.

$$P(D) = P_s \frac{T_s T_t \phi^2}{\partial \pi D^2 \beta} \quad (1)$$

Here, T_s is the transmitting antenna gain, T_t is the receiving antenna gain. α is the wavelength of the signal. D is the communication distance between the sending sensor node to the receiving sensor node. Let β denote the incoming and outgoing line loss. Let φ denote the infactor of channel quality.

Considering the transceiver has the more complex environments such as the obstacles in the middle, based on lognormal model to solve the received power, which is shown in the following formula.

$$P(D) = P_s \frac{10 n \phi^2}{\partial \pi {D_0}^2} + X \quad (2)$$

where, X is mean value when variance is log(β), which is used to characterize the deviation caused by obstacles of body, indoor and outdoor.

Consider the case a node located around the body, the human body by measuring the deployment of the sensor nodes around the chest, with reference to the propagation model using the cylindrical body member domain, the above formula of received power, i.e., the body in a given interval, the received signal power can be expressed as formula (3).

$$P(dB) = -10\log_{10}(P_s \frac{e^{n\phi^2}}{\partial \pi}) + \kappa \quad (3)$$

Here, k is the correction value.

B. Collection Method

In order to achieve adaptive control and node selection, collect real-time status information network currently , which includes channel quality and communication distance. The collection method is expressed as follows:

Step 1 Monitoring the channel state.

Step 2 Collect transmit power and receiving power.

Step 3 Calculate the channel quality based on the results of step 2.

Step 4 Count the distance between the sending node and receiving node.

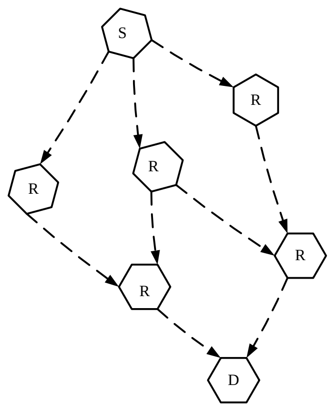

Figure 2. Model of wireless body sensor network topoloty

III. OPPORTUNISTIC COOPERATION BASED ON HEAP SORT

A. Heap Sort Struct

According to the model definition of section II, the heap sort struct was given to sort the candidate sensor nodes with collection approach and search the best realay nodes with the minimized distance or maxized channel quality. The following is the heap definition.

1) The sequence of n elements, which are denoted by$\{k_1, k_2, \cdots, k_n\}$.
2) $k_i <= k_{2i}$ and $k_i <= k_{2i+1}$.
3) $k_i >= k_{2i}$ and $k_i >= k_{2i+1}$.

As long as meeting the above (1) and (2) or (3) points, this complete binay tree would be the heap. If this sequence corresponds to a one-dimensional array as a complete binary tree, is the meaning of the heap:

(1) If the sequence $\{k_1, k_2, \cdots, k_n\}$ is heap, the top elements of the heap shall be the minimum or maximum of the n elements sequence.

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(2) Complete binary tree in all the value of the terminal nodes are not greater than or less than of the value about other sensor nodes

```
Input: j set
Output: list set
(1) i = u, j , temp = list[i];
(2) j = 2 * i;
(3) while (j <= v)
(4)   {
(5)       if(j < v && list[j] < list[j+1])
(6)       {
(7)        j++;
(8)       }
(9)       if(temp < list[j])
(10)      {
(11)              list[i] = list[j];
(12)              i = j;
(13)              j = 2 * i;
(14)      }
(15)      else
(16)              break;
(17)      }
(18)      list[i] = temp;
```

Figure 3. Algorithm of heap asdjust

```
Input:  candidate sensor nodes set
Output: list set with relay nodes
(1) int i = 1,a;
(2) while(scanf("%d",&a)==1)
(3) {
(4)     list[i] = a;
(5)      i++;
(6)    }
(7)   *n=i-1;
(8)  getchar();
(9) output the list array as the relay nodes set
```

Figure 4. Algorithm of create heap list

```
Input: list set of candidate sensor nodes
Output: list set with heap
(1) int i = 0, temp = 0, count = 1;
(2) for (i = n  / 2; i > 0; i--)
(3) {
(4)         heapAdjust(list, i, n);
(5) }
(6) for(i = n ; i > 1; i--)
(7) {
(8)         temp = list[1];
(9)         list[1] = list[i];
(10)        list[i] = temp;
(11)        heapAdjust(list, 1 , i-1);
(12)        printList(list, n);
(13) }
```

Figure 5. Algorithm of heap sort

The basic process of heap sort is as follows:

Step (1): Build an initial heap.

Step (2): Adjust the heap, making it the maximum or minimize heap.

Step (3): The heap top element for elements, the largest exchange roof element and sequence of the last element.

Step (4): The rest of the n-1 elements to build maximum heap, until the end of the sorting.

Heap sort for the low efficiency when the valule of n is lower, but when n is bigger, the efficiency is high, Time complexity of which is O(nlogn).

The pseudocode for the heap sort algorithm of preorder traverse is summarized as Figure 3, 4 and 5.

B. Opportunistic Cooperative Mechanism

The opportunistic cooperative algorithm based on channel quality or distance with heap sort is given by Figure 6, the implementation workflow of which is as follows:

Step (1): Set the candidate sensor node set to the relay selection.

Step (2): Collect the channel quality or communication distance as the coefficient value of sensor node.

Step (3): Initialize the heap according to the coefficient value such as channel quality or distance.

Step (4): Get the heap head node as the optimal relay sensor nodes, repeat (2) - (3) until the set is empty.

Step (5): Update the channel information such as nodes set, channel quality or distance array.

Step (6): Create the cooperative routing based on step (2)-(5), until the data packets received successfully by the receiver or dropped by the sender node.

```
Input: sensor node set
Output: transmission routing array
(1) Get candidate node set {j[n]}.
(2) Collect the network state information array: Cq[i] and D[i].
(3) Implement heap Adjust function with coefficient value of
     Cq[i] and D[i].
(4) Implement heapSort function.
(5) for (k=1; k<=n; k++,n--) &&(n>0)
(6){
(7)        Get the heap head node;
(8)        m=Cq[k];
(9)        t=D[k];
(10) }
(11) Update  Cq[i] and D[i].
```

Figure 6. Algorithm of opportunistic cooperation

IV. PERFORMANCE EVALUATION

In this section, we analyzed the reliable transmission scheme based on opportunistic cooperation scheme (OCTS) for wireless body sensor networks with the traditional transmission scheme (TTS) through four group experiments. The average experimental data was obtained after 1000 time experiments and numerical analysis. The parameter settings is detailed on Table I.

TABLE I. PARAMETER SETTINGS

Parameters	Value
Transmission power	-8dbm
Received power	-10dbm
Path loss	2
Single hop delay	0.1ms
Number of nodes	10-100
Communication range	0.1-2 m
Data packet size	1500 bits
Data packet generation rate	0.01 per second
Simulation time	1000 s

We make the following assumptions in our experiments and numerical analysis:

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(1) Sensor nodes are equal, fixed and have the same initial energy.

(2) Only consider the energy consumption in the process of processing and data transmission.

(3) Only consider the from one to three hops communication from the cluster head nodes or cluster sensor nodes to sink nodes.

(4) Sensor nodes are in a continue working condition that means no sleep state.

Considering the scalability and pertinence of the wireless body sensor network, our work use the average system throughput ratio, average end to end delay and average energy consumption ratio to measure and analyze the performance of the proposed OCTS and TTS, which refer to all successfully reveived packets by the sink node from the other sensor nodes.

(1) The average system throughput ratio means the ratio of the successfully received data packets number to the amount of data can be transmitted per unit time to the sink node, which was used to evaluate the transmission ability of the transmitted schemes with the distance, channle quality or hop number.

(2) The average end to end delay means the system time of all successfuly reach the sink node data packets from each node with the communication distance, signal to noise ratio and hop number, which was used to measure and test the real time performance of the transmission schemes.

(3) The average energy consumption ratio means the ratio of the total energy consumption to one of all the successfully reaching the sink nodes with the number of sensor nodes, distance or channel quality.

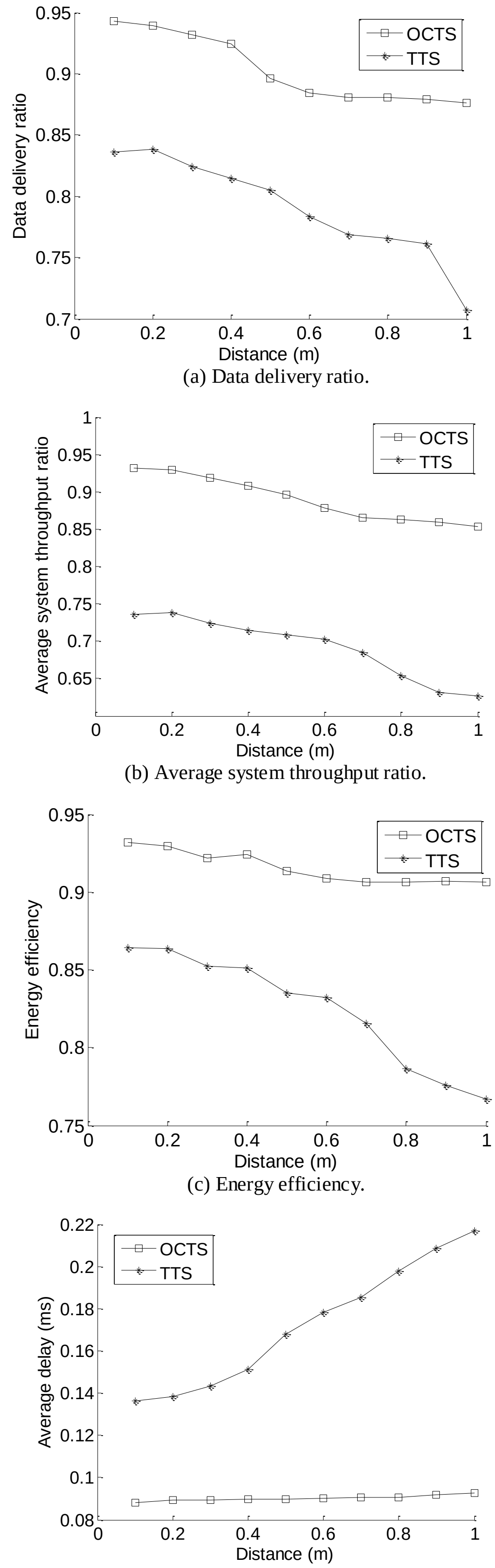
Assuming that, the wireless body sensor networks topology is distributive and random, let w denote the signal to noise ratio of the channel between sensor node S to sink node SN. In addtion, let R_n denote the relay node number of S, which could be selected for forwarding data packets belonging to S. Hence, the successfully received data packets ratio P_{SSN}could be obtain by the following formula:

$$P_{SSN} = \prod_{i=1}^{n} w\Re(SSN) \tag{4}$$

Let D denote the communication distance from sending sensor node to sink node and H denote the hop number. Then the average end to end delay T could be calculated by following formula:

$$T = \frac{1}{P_{SSN}} \sum_{i=1}^{H} \frac{H}{(1-w(1-\Re(SSN)))D} \tag{5}$$

In experiment 1, performance of traditional transmission scheme (TTS) and the proposed opportunistic cooperation (OCTS) were compared with the transmission distance, which are shown in Figure 7. Figure 7 gives the analytical conclusions of the above transmission mechanisms with data delivery ratio, average system throughput ratio, energy efficiency and average delay. From the experimental results show that the change of the communication distance of OCTS and TTS influence is very big with the increasement of communication distance. The data delivery ratio gradually reduce, system throughput ratio and energy efficiency is also to be reducing. On the other hand, the



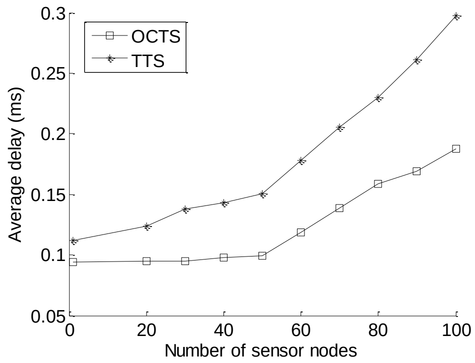
(a) Data delivery ratio.

(b) Average system throughput ratio.

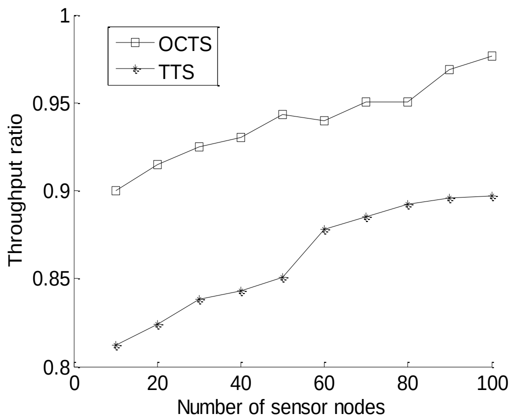
(c) Energy efficiency.

(d) Average delay

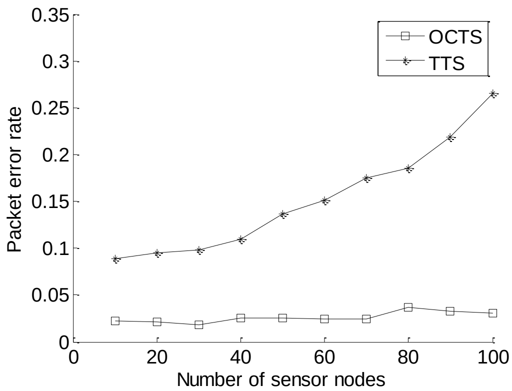
Figure 7. Performance with distance



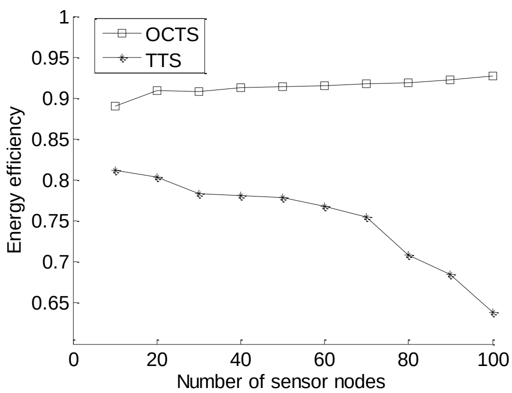
(a) Average delay.



(b) Throughput ratio.



(c) Packet error rate.



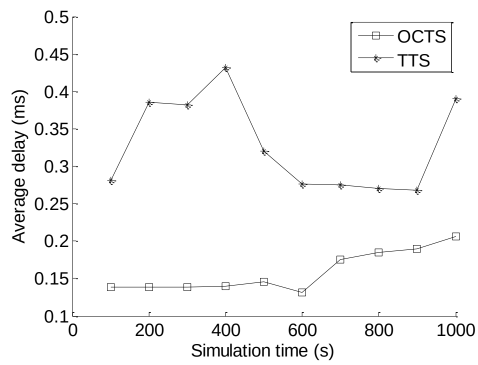
(d) Energy efficiency.

Figure 8. Performance with number of nodes

delay in increasing. The proposed OCTS scheme change curve leveled off, however, reduced volatility, making data transmission is more smooth. Reduced throughput ratio, increasing delay with every 0.3 difference of distance, OCTS slope values will fall by about 10%. Also found from the analysis, OCTS is 0.1 from the difference the average consume less energy, reduce energy consumption by around 23%. This is because, with the increase of distance, channel quality worse and worse, thus causing the throughput decreases, and time delay increase. For OCTS, transmission mode based on collaboration and the opportunity to choose a relay node, increased to reduce the distance of communication performance, the influence of the throughput rate is reduced, delay increase, the fall of the energy efficiency is more and more small, even under the condition of long distance communication, sensor nodes with the OCTS can still achieve better performance in throughput and delay.

In order to further analyze the above indicators, we compared the proposed OCTS and the traditional TTS performance in the second set of experiments as shown in Figure 8. Simulation scenario as mentioned above, the relevant index to the experiment is shown in Table 1, the values of w in the proposed OCTS and TTS are 1 and 2 respectively, the initial value of D is 0.5.

Respectively under different size of wireless body sensor network is given, and the above two kinds of data transmission mechanisms in delay, throughput ratio, packet error rate and energy efficiency of the simulation results. It can be seen from the result that in small wireless body sensor networks, throughput ratio gap of the OCTS and the traditional TTS is small, with the increasing of data rate and the expanding of network size, the OCTS and TTS gradual Throughput degradation, but still OCTS than other protocol has higher throughput. In terms of average delay, the delay of TTS has been always the longest, OCTS is influenced by the relative to the minimum. This is because the TTS needs certain negotiation mechanism and the dormancy mechanism, under the large-scale network, is bound to cause the loss of efficiency, but based on the collaboration ways of OCTS is affected by this small. In terms of energy consumption and reliability, OCTS showed the optimal energy saving features and reliabilityj, ones of the TTS are the worst. Can be seen from the above analysis, OCTS under various network scale are very suitable for state-controlled bharat sanchar nigam, show the good performance.



(a) Average delay.

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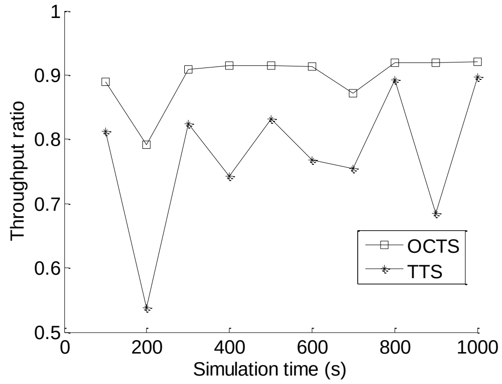
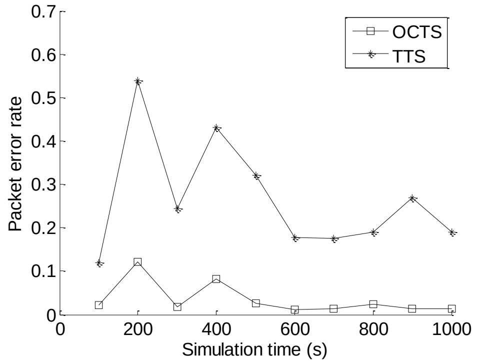
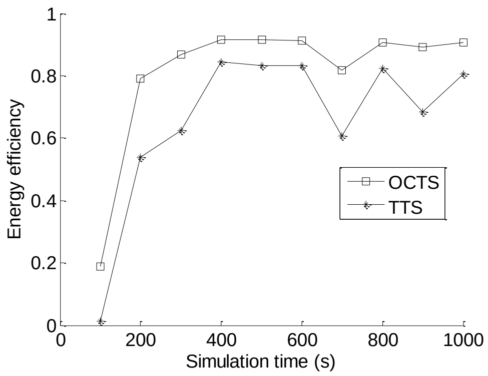


(b) Throughput ratio.



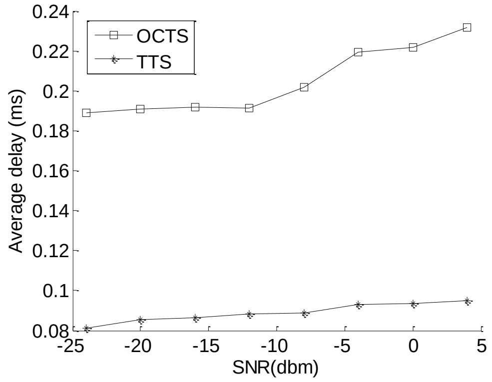
(c) Packet error rate.



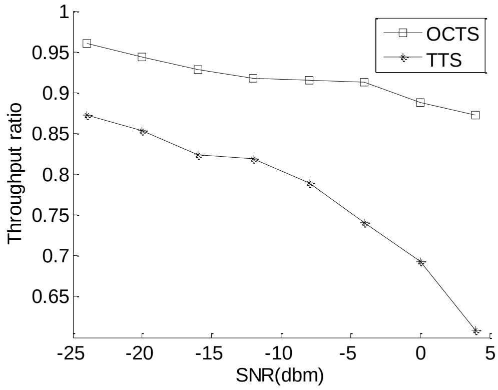
(d) Energy efficiency.

Figure 9. Performance with simulation time

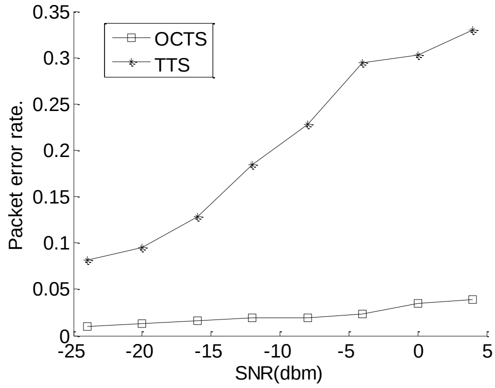
The accuracy and effectiveness of the proposed OCTS is studied through the experiment 3. Using 5 sensor nodes as a state-controlled bharat sanchar nigam limbs and head nodes in a monitored object, using the 6 sensor node as a collection of base stations, and the human body attenuation is about 22 dbm, Beacon cycle set as 0.35. Assuming that the simulation experiments are conducted in a small office and measured object or random flap or sport do indoors, base station nodes are placed around the walls and ceiling. In the experiment, the results using OCTS and TTS have collected 1000 seconds time to generate data. The average delay, throughput ratio, packet error rate and energy efficiency are shown respectively in Figure 9 (a), (b), (c) and (d). From the results of Figure 9, the performance of OCTS such as throughput ratio, packet error rate and energy efficiency is superior to the performance of the TTS. With the increase of the simulation time, OCTS forward collaboration success rate gradually to increase, further increase the accuracy of the system, base station node increases throughput and reduce the energy efficiency.



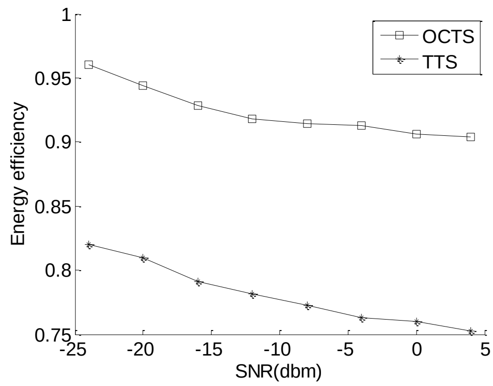
(a) Average delay.



(b) Throughput ratio.



(c) Packet error rate.



(d) Energy efficiency.

Figure 10. Performance with channel quality

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In experiment 3, the sensor nodes with different qualify of transmission channel, performance analysis of data quality is shown in Figure 10. We can see that the OCTS best performance according to four performance indicators, which has the highest success rate of data transmission, the lowest average delay and pakcet error rate, as well as the better control of average energy consumption. The TTS strategy due to allow the sensor nodes only when meeting point to submit the message queue, very low transmission power consumption, but as a result of the node is hard to meet focal point, thus cause great average delay and low success rate of transmission. For OCTS scheme, cooperative transmission of packets due to the different sensor nodes can be selected to forward to the focal point, and at a chance to choose the best relay nodes, has the high transfer success rate and low delay. And the TTS generally transport the data packets from the node to the focal point, so in general, transmission performance of the OCTS is better than the TTS.

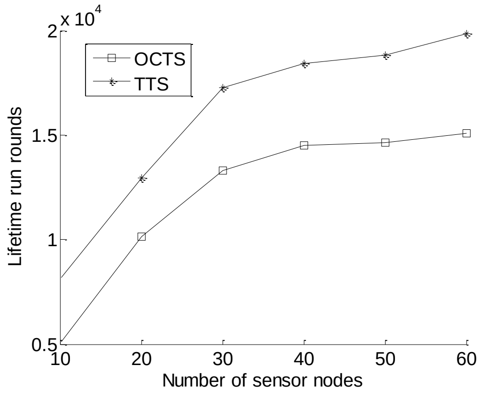

Figure 11. Lifetime run rounds

As shown in Figure 11, the proposed OCTS scheme is ablel to provide better lifetime than the traditional TTS with the increasement of wireless body sensor network.

V. CONCLUSIONS

This work proposed an reliable transmissopm scheme based on opportinistic cooperative approach with heap sort according to channel quality or distance, which is used to improve the reliability of data communication and transmission performance in wireless body sensor networks.

This scheme researches and collectes the characteristics of channle quality or distance with wireless body sensor networks at first. Secondly, the optimal relay nodes would be selected by heap sort based on the opportunitic cooperative mechanism, which is used to make the choice of relay nodes and obtain the optimal data transmission scheme. In this scheme, the heap sort method was used with the complete binary tree structure and minimize or maxmize heap in wireless body sensor networks communication. The mathematical evaluation and simulation results test that this proposed OCTS scheme could significantly enhance the wireless communication reliability, the real time performance, system lifetime and sysytem traffic as well as decrease the energy comsumption.

REFERENCES

[1] Ionescu, C.M.; De Keyser, R. “Relations Between Fractional-Order Model Parameters and Lung Pathology in Chronic Obstructive Pulmonary Disease,” *IEEE Transactions on Biomedical Engineering*, Vol. 56, no. 4, pp. 978 - 987, 2009.

[2] Krow, C.M. “Nanotechnology and Asbestos: Informing Industry About Carbon Nanotubes, Nanoscale Titanium Dioxide, and Nanosilver,” *IEEE Nanotechnology Magazine*, Vol. 6, no. 4, pp. 6 - 13, 2012.

[3] Jinli Suo; Xilin Chen; Shiguang Shan et.al. “A Concatenational Graph Evolution Aging Model,” *IEEE Transactions on Pattern Analysis and Machine Intelligence*, Vol. 34, no. 11, pp. 2083 - 2096, 2012.

[4] Hongtao Ma; Tae-Kyu Lee; Dong Hyun Kim et.al. “Isothermal Aging Effects on the Mechanical Shock Performance of Lead-Free Solder Joints,” *IEEE Transactions on Components, Packaging and Manufacturing Technology*, Vol. 1, no. 5, pp. 714 - 721, 2011.

[5] Xiaoyu Zhang; Hanjun Jiang; Lingwei Zhang, et.al. “An Energy-Efficient ASIC for Wireless Body Sensor Networks in Medical Applications,” *IEEE Transactions on Biomedical Circuits and Systems*, Vol. 4, no. 1, pp. 11 - 18, 2010.

[6] Tao Gu; Liang Wang; Hanhua Chen, et.al. “Recognizing Multiuser Activities Using Wireless Body Sensor Networks,” *IEEE Transactions on Mobile Computing*, Vol. 10, no. 11, pp. 1618 - 1631, 2011.

[7] Raveendranathan, N.; Galzarano, S.; Loseu, V. et.al. “From Modeling to Implementation of Virtual Sensors in Body Sensor Networks,” *IEEE Sensors Journal*, Vol. 12, no. 3, pp. 583 - 593, 2012.

[8] Yoo, J.; Long Yan; Seulki Lee, et.al. “A 5.2 mW Self-Configured Wearable Body Sensor Network Controller and a 12 μ W Wirelessly Powered Sensor for a Continuous Health Monitoring System,” *IEEE Journal of Solid-State Circuits*, Vol. 45, no. 1, pp. 178 - 188, 2010.

[9] Shih-Lun Chen; Ho-Yin Lee; Chiung-An Chen et.al “Wireless Body Sensor Network With Adaptive Low-Power Design for Biometrics and Healthcare Applications,” *IEEE Systems Journal*, Vol. 3, no. 4, pp. 398 - 409, 2009.

[10] Yong Jin, “High Reliable Relay Selection Approach for QoS Provisioning in Wireless Distributed Sensor Networks,” *International Journal of Distributed Sensor Networks*, vol. 2013, Article ID 216478, 11 pages, 2013.

[11] Qiang Fang; Shuenn-Yuh Lee; Permana, H. et.al. “Developing a Wireless Implantable Body Sensor Network in MICS Band,” *IEEE Transactions on Information Technology in Biomedicine*, Vol. 15, no. 4, pp. 567 - 576, 2011.

[12] Xiyu Lu; Xinlei Chen; Yong Li et.al. “ZebraBAN: a heterogeneous high-performance energy efficient wireless body sensor network,” *IET Wireless Sensor Systems*, Vol. 3, no. 4, pp. 247 - 254, 2013.

Xuebing Dai was born in1973, in Qingdao Shangdong. He is a doctor. He is the engneer in the management office of the software system.

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Yan Zhang was born in1974, in Qingdao Shangdong. He is a doctor. He is the engneer in Qingdao electric government information office.

Chaojing Wang was born in1979, in Qingdao Shangdong. He is a doctor. He is the engneer in Information resources management, Qingdao electric government information office.

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