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Wireless Sensor Network in the Virtual MIMO Energy-saving Transmission Scheme

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Abstract

Wireless sensor network (WSNs) is more and more attention from researchers in recent years. Wireless sensor network (WSN) is a large number of sensor through the way of wireless communication, mutual connection, the processing, the transmission of information network, can be real-time monitoring, perception and gathering network distribution area of various environmental monitoring object information, or information to process and transmit the information to the user. This article was based on the virtual MIMO STBC space-time coding technology combined with a cluster head cooperative transmission architecture, this paper proposes a suitable for clustering wireless sensor network based on STBC energy-saving transmission scheme of virtual MIMO space-time coding based on STBC based space-time coding in the MIMO system ber performance analysis, SCHCT scheme of the overall energy consumption model is established.

Keywords: *MIMO; Wireless SensorNetworks; STBC; SCHCT*

1. Introduction

Wireless sensor network (WSN) is a large number of sensor through the way of wireless communication, mutual connection, the processing, transfer of information network. The network integrated sensor technology, embedded computing technology, distributed information processing technology and communication technology, can be real-time monitoring, perception and gathering network distribution area of various environmental or monitoring object information, and to handle the information properly, send it to the required the user. Wireless sensor networks in military, traffic, meteorology, industrial and agricultural production, biological, security, health, family and other fields have a wide range of applications, especially in some humans can not arrive or can't work environment, can replace human collection, information processing needs. The research, development and application of wireless sensor network (WSN), related to national security, economic development, and other significant aspects, on the domestic and international in recent years has caused wide attention and investment. Mobile wireless sensor networks is to add mobility in wireless sensor network (WSN), using the movement of the sensor nodes or proxy node movement technique of network coverage, the expansion of network capacity and save the network energy consumption, balance the distribution of the network energy consumption and prolong the network life, convenient and quick access to the Internet, etc. The movement of the wireless sensor network node or mobile agents, mobile devices and general sensor network node in its energy, computing power, storage capacity and transmission distance is not restricted, so you can put in the wireless sensor network data collection, storage,

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processing, remote transmission, access to the Internet for tasks such as to it, then save the network energy costs, extend the service life of wireless sensor network (WSN).

Multiple input multiple output (MIMO) because that could improve the system in the multipath fading channel transmission capacity, has been widely used in cellular wireless and broadband access systems [2]. Under the same reliability requirements, MIMO system than single input single output (SISO) systems need less transmission energy. But due to the volume restriction, sensor nodes in a sensor node to realize multiple antenna transmission is not feasible in practice, therefore, the Virtual MIMO (Virtual MIMO) or Virtual multi-antenna technology with single antenna, is proposed for multiuser or multi-node cooperative communication. Existing research shows that when the transmission distance is greater than a certain value, the virtual MIMO technique is applied to wireless sensor network (WSN) than a single antenna transmission technology to save energy consumption [3]. [10], even considering the training began to pin for MIMO transmission, virtual MIMO can also achieve the goal of energy saving. [11] proposed a multiple hops V - BLAST virtual MIMO transmission scheme, and through parameter optimization to maximize the network life span. But these studies are only for simple point-to-point single jump model, did not consider the whole wireless sensor network. Recent studies have also USES the virtual MIMO multiple hops transmission to realize the communication between clusters in order to save energy consumption, through multiple hops transmission transmit the data to a data collection station [12]. [13] with V - BLAST space-time encoding expanded the literature [12]. However, this method applies only to the base station, in the case of sensor monitoring area, or near, in the base station sensor monitoring area is relatively far away, long distance transmission energy consumption accounts for most of the overall energy consumption, multiple hops transmission and no practical significance. In addition, this method does not consider the multiple hops transmission of the message exchange routing table set up need energy consumption, such as lack of realizability.

Collaborative virtual MIMO technique based on STBC though need to send to the local communication and collaboration between nodes for joint coding, but because of STBC coding can achieve transmit diversity, not only can receive diversity gain, STBC is to obtain the simplest space-time transmit diversity code, has been widely used in mobile communication. The representative STBC is put forward by the earliest Alamouti scheme [11], the scheme using two transmit antennas transmit diversity scheme, is also one of the most simple of STBC coding scheme. When the channel is flat fading channel, the launch of the continuous time is constant, the channel characteristics, the receiver of STBC can obtain the diversity gain is equal to the product of the number of transmit antennas and receive antennas. Therefore, STBC at the expense of the coding gain and part of the band utilization rate for the maximum diversity gain. STBC decoding complexity is low, is a kind of simple practical and the performance is relatively good space-time codes. Research by Tarokh *et al.*, [15], based on Alamouti scheme, based on the generalized orthogonal design principle, STBC can be extended to arbitrary transmitting antenna. Have a lot of related research is discussed based on STBC coding of collaborative virtual MIMO transmission technology. In the literature [2], the authors put forward a model used to analyze the circuit power consumption and transmission energy consumption at the same time, the energy efficiency of MIMO and cooperative MIMO. The research results show that when the transmission distance is greater than a certain threshold, MIMO and cooperative MIMO transmission mode is more save energy than SISO mode of transmission. In reference

[3], this paper puts forward a more accurate model of virtual MIMO transmission based on STBC, this model considers the training for MIMO transmission overhead. In ref. [4] the author puts forward a cooperative transmission scheme based on STBC used for wireless sensor network (WSN) lack of accurate synchronization. However, these solutions only used single jump the MIMO transmission without considering the specific application of wireless sensor network. [5] put forward a different scheme, joint considering multiple hops and MIMO transmission, used to save the communication between the energy consumption. However, in this scheme, the Sink near the monitoring area, when the Sink is out of the monitoring area is far away or near, because of long distance transmission accounted for most of the energy consumption and energy consumption monitoring area of multiple hops MIMO transmission is unnecessary.

This paper proposes a collaborative virtual MIMO based on STBC space-time coding transmission scheme, namely SCHCT scheme [I9]. And based on STBC MIMO communication model on the basis of energy consumption, SCHCT scheme of the overall energy consumption model is established, through comparing with LEACH solution and the simulation analysis, get SCHCT scheme of energy consumption characteristics.

2. System Models

When the Sink are far away from the monitoring area, traditional clustering protocol using a single cluster heads to the Sink transmission consumes a lot of energy. As shown in Figure 1, by N wireless sensor network node random distribution in the area of square $M \times M$ meters. Sink far outside the region, there was a command or as a base station receives the packet and information. All sensor nodes in the official start of the working hypothesis was Sink before synchronization, and assume that each node has the GPS module, and can adjust their transmission power according to the circumstance arriving at any node, including the Sink. Assume that the Sink is equipped with multiple antennas for implementing MIMO transmission. Each node in a cycle transmission one bit of data packets to the cluster head nodes. And similar, VCHCT SCHCT scheme of operation process is divided into rounds, each round is a cycle. Each round consists of three stages, namely cluster formation stage, stage of stable transmission, cooperative transmission phase.

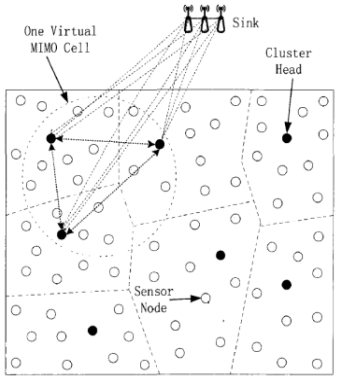

Figure 1. System Model

1) cluster formation stage

At this stage, a distributed clusters based on LEACH algorithm, all sensor nodes self-organized terrain component cluster. In the beginning of each round, on the basis of LEACH specified probability P, the election of each node itself as cluster head nodes. Each cluster heads, after the completion of election of cluster using the CSMA protocol sends a broadcast message to all other nodes in the area, the message contains the cluster head's ID. Then, sensor nodes according to the cluster heads broadcast messages received signal strength to select a recent clan head and request to join the cluster. Cluster message by sending a request to join the to the nearest cluster head, cluster heads to record the new cluster member's ID number. Formed after the cluster head will establish a TDMA scheduling table used for the transmission of all members of the cluster scheduling, and to bring the broadcast scheduling table sent to every member in the cluster.

(2) stable phase

At this stage, similar to LEACH, cluster members through a series of wipes her virginity to send the data to the cluster head nodes. In each frame, each cluster member nodes will use in the TDMA scheduling table of forming the scheduled time slot to send data, and in other time slot into sleep mode to save energy consumption. When the cluster heads after receiving the data from all the members of the family meal, it will be to receive data for data fusion in order to eliminate data redundancy.

(3) collaboration transmission phase

After the completion of the data fusion, cluster heads will wait for the polling broadcasting news from the Sink. After the cluster head receives the broadcast news, it will respond to a reply message. This reply message contains the ID number of cluster heads and their location information. Based on the information in this reply message, the cluster head Sink into groups to form a virtual MIMO unit, and established for each virtual MIMO unit TDMA transmission scheduling. This grouping and transmission scheduling information sent via radio to each clan head node] in a virtual MIMO transmission unit within the cluster head nodes according to the grouping information collaboration to form a virtual antenna array. Each within the virtual MIMO transmission unit distribution of head nodes according to the previous time slot, the family through radio sends its own data transmission unit within the other clan head node. When virtual MIMO transmission unit within all the cluster head nodes after receiving the data of other cluster head nodes, will be based on STBC [6] sequence coding principle of transmission. Sink design transmission scheduling table will determine which virtual MIMO transmission unit to send, send, after which, in turn. In the given time slot scheduling, Sink will request virtual transmission unit of data transmission. If there are no enough the last cluster head to form a virtual antenna array, and then assume that Sink can adjust the transmitting antenna number, form the SIMO transmission system according to the situation.

3. SCHCT Scheme Analysis of Energy Consumption

According to the communication model of energy consumption, this section will be set up within the cluster transmission, transfer and distance between cluster virtual MIMO transmission unit energy consumption model of bits, and on this basis to establish SCHCT schemes of the total energy consumption model. The analysis, it was

assumed that Sink there is no limit to the energy consumption. In addition, the modulation scheme using a fixed rate of BPSK modulation.

In order to establish the total energy consumption model of SCHCT system, we need to send and receive a bit of variety to be established in communication, communication between clusters, and virtual MIMO communication model of energy consumption. According to [2], send the total power consumption consists of two parts, namely all the power consumption of power amplifier and the energy consumption of the circuit module. Therefore, to send a bit of the energy consumption can be defined as:

$$E_{bt} = \frac{P_{PA} + P_C}{R_b} \tag{1}$$

E_{bt} representative when considering the energy consumption of electric circuit and the transmission energy consumption, sending one bit of the total energy consumption. R_b is the bit rate of the system. The total power consumption of power amplifier can be approximate to:

$$P_{PA} = (1+\alpha) P_{out} \tag{2}$$

Which $\alpha = \xi/\eta - 1$ said the dissipation efficiency of rf power amplifier, ξ is dependent on the modulation mode and constellation size than the peak. For sending power transmission P_{out} distance based on the different corresponding model. If the transmission distance above a certain threshold, the use since. By space model; On the other hand, the two diameter ground reflection model is used. Thus it can be estimated for the next type:

$$P_{out} = \begin{cases} E_b R_b \dfrac{(4\pi)^2 M_t N_f}{G_t G_r \lambda^2} d^2 & d \le d_0 \\ E_b R_b \dfrac{M_t N_f}{G_t G_r h_t^2 h_r^2} d^4 & d > d_0 \end{cases} \tag{3}$$

Type E_b is given under the condition of BER receiver side P_b needed every bit of the average energy consumption, R_b is the bit rate, d is the transmission distance, d_0 is the transmission distance threshold, defined as $4\pi h_t h_r / \lambda$. G_r and G_t are receiver antenna gain and transmitter antenna gain, defined as the carrier wavelength, h_t and h_r, respectively for the transmitter and receiver antenna height, M_t compensation for the link, N_f is used to compensate the hardware change process and other additive background noise or interference. N_f is the receiver noise system, defined as $N_f = N_r / N_0$. , which N_0 is the unilateral thermal noise power spectrum density at room temperature, N_r is the receiver input total effective noise power spectral density.

Said, P_{ct} each in and sending and P_{cr} receiving circuit of power consumption, according to [2], P_{ct} can be estimated as follows:

$$P_{ct} \approx P_{DAC} + P_{mix} + P_{filter} + P_{syn} \tag{4}$$

P_{cr} can approximate estimation as follows:

$$P_{cr} \approx P_{LNA} + P_{syn} + P_{mix} + P_{IFA} + P_{filt} + P_{ADC} \tag{5}$$

Among them, P_{LNA}, P_{syn}, P_{mix}, P_{IFA}, P_{filt}, P_{ADC} respectively D/A converter, A/D converter, mixer, frequency synthesizer, the sender filter, low noise amplifier, intermediate frequency amplifier, the receiving end of active filter and power consumption.

Use of virtual MIMO transmission based on STBC coding, Rayleigh fading channel and two ground reflection model. Multi-input multi-output (MIMO) system, therefore, the average bit error rate can be expressed as [7] :

$$\overline{P_b} = \frac{2}{b}\left(1-\frac{1}{2^{b/2}}\right)\frac{1}{2^{M_T M_R}}\left(1-\frac{1}{\sqrt{\mu}}\right)^{M_T M_R}\sum_{k=0}^{M_T M_R}\frac{1}{2^k}\binom{M_T M_R-1+k}{k}\left(1+\frac{1}{\sqrt{\mu}}\right)^k \quad (6)$$

where

$$\mu = 1+\frac{2N_0}{E_b} \quad (7)$$

Among them, b is the constellation size, for BPSK system, $b=1$. M_T and M_R represent the number of the sender and the receiver antenna. To simplify, hypothesis $M_T = M_R$. For a particular needs every bit of the average energy consumption and bit error rate can be obtained by reverse thrust (6).

Use E_{bt_MIMO}, E_{bt_inter} and E_{bt_intra} respectively send a bit of distance between MIMO transmission, transmission and communication energy consumption of the cluster within. According to the type (1) to (7) available:

$$E_{bt\_MIMO} = (1+\alpha)E_{b\_MIMO}\frac{M_t N_f}{G_t G_r h_t^2 h_r^2}d_{tos}^4 + \frac{M_T P_{ct}}{R_b} \quad (8)$$

d_{tos} said the average distance from the cluster to the Sink, R_b is the system of the bit rate, and assuming equal to Bb, B is the transmission bandwidth of the system. Is for a specific bit error rate under the demand for energy consumption per bit, and E_{bt_MIMO} can be obtained by reverse thrust (6).

For communication, using Rayleigh fading channel and free space model, therefore, to send a bit of the energy consumption can be expressed as:

$$E_{bt\_inter} = (1+\alpha)E_{b\_inter}\frac{(4\pi)^2 M_t N_f}{G_t G_r h_t^2 h_r^2}d_{CtosC}^4 + \frac{M_T P_{ct}}{Bb} \quad (9)$$

One is for a given bit error rate for peak demand every bit of energy consumption, can be obtained by reverse thrust (10)

$$P_b = \frac{N_0}{\frac{1}{(1-2P_b)^2}-1} \quad (10)$$

Set d_{CtosC} in the same virtual MIMO transmission within the cluster heads to the average distance of the cluster heads. The average area of each cluster can approximate to M^2/K_C, the total number of clusters is K_C monitoring area. In order to simplify the analysis, K_C assuming the M_T multiples. So, a virtual MIMO transmission unit of area can be approximate $M^2 M_T/K_C$. Monitoring area assumed to be the body shape, has a maximum distance of two nodes as a square diagonally line, so d_{CtosC} can be expressed as

$$E_{bt\_intra} = \frac{N_0 \left(Q^{-1}\left(P_b\right)\right)^2}{2} \tag{12}$$

d_{CtosH} is from cluster member to the average distance of the cluster heads, according to [1] d_{CtosH} can be approximated as:

$$E\left[d_{CtosH}^2\right] = \frac{M^2}{2\pi K_c} \tag{13}$$

Finally, to receive a bit of energy, E_{br} can be approximate to:

$$E_{br} = \frac{P_{cr}}{Bb} \tag{14}$$

3.2. SCHCT in Overall Energy Consumption Model

SCHCT scheme of energy consumption consists of two parts: one is for head node energy consumption, the second is the energy consumption of the cluster member nodes. If there is K_c family, every cluster node, that is, a cluster head nodes and $N/K_c - 1$ cluster member nodes. Use E_{CH} and E_s cluster of respectively the energy consumption and the energy consumption of the cluster members, within a cluster of the total energy consumption $E_{cluster}$ can be expressed as:

$$E_{cluster} = \left(\frac{N}{K_C} - 1\right) E_s + E_{CH} \tag{15}$$

For each cluster head nodes, the energy consumption by receiving cluster member data, receive data fusion, send the data to the collaboration of the fused, receiving from other cluster head nodes of cluster nodes of the fused data, through the virtual MIMO transmission technology of the encoded data sent to the Sink of the five parts. As a result, the total energy consumption of cluster nodes can table is to:

$$E_{CH} = L\left(\frac{N}{K_C} - 1\right) E_{br} + L\frac{N}{K_C} E_{DA} + L\left(M_T - 1\right) E_{br} + LE_{bt\_inter} + LE_{bt\_MIMO} \tag{16}$$

The second cluster for data fusion is the energy consumption. Such as the literature [1], assumes that the cluster head received all the data to carry on the total integration, which E_{DA} is every bit of fusion energy consumption. For marriage within the node, just send the data to the cluster head nodes, as a result, the energy consumption can be represented as:

$$E_s = LE_{bt\_intra} \tag{17}$$

Based on the above analysis, SCHCT solution can be obtained in a cycle of total energy consumption as follows:

$$E_{total} = K_C E_{cluster} \tag{18}$$

4. Simulation Results

In the simulation, 400 nodes randomly distributed in the 200×200 square meters of sensor monitoring area. Other parameters of system are as follows: $f_c = 2.5GHz$,

$B = 10kHz$, $\alpha = 0.4706$, $M_T = 40dB$, $N_f = 10dB$, $G_t G_r = 5dBi$, $h_t = h_r = 1m$, $N_0/2 = -174dBm/Hz$; $P_{ct} = 98.2mW$, $P_{cr} = 112.6mW$, $P_b = 10^{-3}$, $E_{DA} = 50nJ$, $L = 4000bits$.

Figure 2 reflects the total energy consumption of LEACH and SCHCT distance as the monitoring area to Sink the heart of change and change. Can be seen in the figure, when heart distance is greater than a threshold, the proposed SCHCT scheme than LEACH and energy saving. On the other hand, with distance ^ ^ ^, energy saving effect of SCHCT also increases. As shown in Figure 2, when is equal to 4, SCHCT energy more efficiently than LEACH the critical distance of 190 meters, more than the distance, SCHCT will more energy-saving than LEACH. When is equal to 8, the critical distance of 225 meters. Reasons, when the distance is small, between clusters and cluster communication energy consumption accounts for the main part of the seven. So when the distance is less than a certain threshold, LEACH is more energy efficient. However, with the increase of distance, long distance transmission becomes the main part of energy consumption, so when is greater than a certain threshold, SCHCT scheme will be more energy efficient.

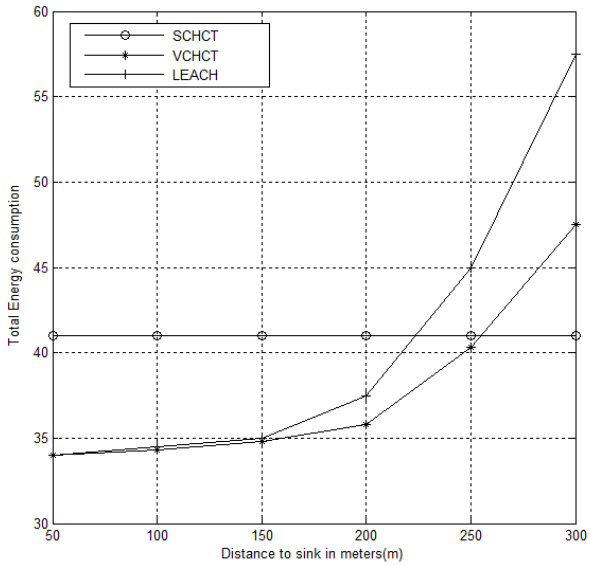

Figure 2. Consuption Vs d_{toS}

Figure 3 reflects the LEACH, VCHCT and SCHCT solutions of total energy consumption change with the increase of the distance to the Sink, from the comparative analysis in the graph can get three important conclusions:

First, three schemes of the energy consumption increases with the increase of the yuan. Seems to SCHCT total energy consumption in the picture does not change with increasing, is actually SCHCT total energy consumption in a relatively few hours growth, especially compared with LEACH, the VCHCT plan growth of energy consumption is relatively small, therefore see little change in the picture.

Second, can be seen from the figure VCHCT solution is always better than LEACH solution and energy saving, and as the, the increase of VCHCT solution compared with LEACH save energy is also increasing. This is because the VCHCT scheme, sending the clan head don't need a bunch of cooperation and no excess energy consumption; In addition, with the increase of long distance transmission energy consumption becomes the main part of the total energy consumption,

so as the increase of VCHCT scheme to save power consumption compared with LEACH also increases.

Third, SCHCT solution compared with LEACH, the VCHCT plan can be seen, as long as s is greater than a certain value, SCHCT solutions than LEACH and VCHCT energy saving. As shown in figure in, when compared with LEACH, the threshold is 225 meters, when compared with VCHCT threshold is 260 meters. Because when comparing hours, SCHCT scheme transmitted to the communication between the energy consumption of cluster of main parts, so when lower than the threshold, LEACH and VCHCT than SCHCT energy-saving. As? Increased and more than a certain threshold, the long distance transport become the main part of energy consumption, so SCHCT than LEACH energy-saving. And VCHCT compared with SCHCT, since there is no emission set gain and coding gain, so when is greater than a certain threshold, SCHCT is more energy-saving than VCHCT.

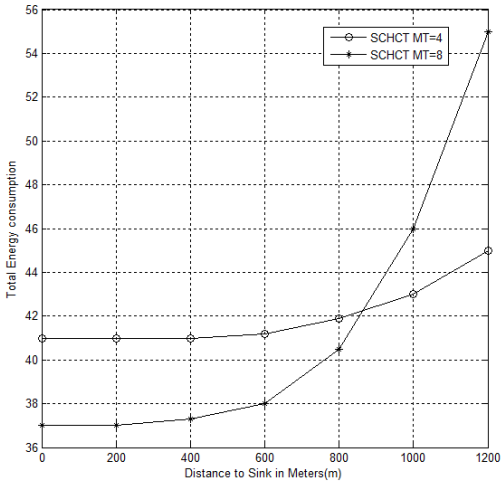

Figure 3. Three Kinds of Scheme Comparison

5. Conclusion

This paper proposes a virtual MIMO transmission scheme based on STBC coding SCHCT for wireless sensor networks and energy saving, and deduced the cluster-heads model based on energy consumption of communication transmission, transmission between clusters, and virtual MIMO transmission over a long distance formula of energy consumption and SCHCT scheme of total energy consumption model is established. Compared with LEACH solution, numerical and simulation results show that when the distance away from the Sink more than a specific threshold method, especially under the condition of the monitoring area far from Sink comparison, the proposed SCHCT scheme can greatly prolong the life of sensor networks.

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