Spatial Correlation-Based MAC Protocol for Event-Driven Wireless Sensor Networks

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***Abstract*—Wireless sensor networks is highly spatial correlated. Recently it has been proposed to select a subset of sensors nodes to transmit their data so as to prevent transmission of redundant data. In this paper, we investigate the ways of selecting sensor nodes and develop a novel spatial correlation-based Medium Access Control (MAC) protocol for event-driven wireless sensor networks, referred as SCMAC. Based on a theoretical framework, SCMAC adopts priority node selection algorithm and collision avoidance mechanism so that transmission of redundant data is prevented when contending for the shared channel, while SCMAC prioritizes the transmission of route-thru packets. Simulation results show that our protocol achieves higher performance than CC-MAC in the aspect of energy consumption, transmission latency, packet delivery rate, packet drop rate and reconstruction distortion.**

***Index Terms*—wireless sensor networks, spatial correlation, MAC, energy consumption, reconstruction distortion**

I. INTRODUCTION

Event-driven wireless sensor networks (WSN) rely on dense deployment of sensor nodes observing physical phenomenon. In dense WSN application, once an event of interest happens, several sensor nodes will detect event information which is highly spatially correlated [1]. When every sensor node transmits its data about sensed event to the sink resulting in the transmission of redundant data. At the some time, it increases contention among the sensor nodes in the wireless medium, resulting in increasing the energy consumption due to collisions. In fact, it is not necessary for all sensor nodes to send its data to sink. Instead, a smaller number of sensor nodes can be enough to transmit event information to the sink [2].

Since sensor node's energy is limited, the energy of senor node mainly consume in the process of sending data. Therefore, there have possible approaches to reduce the number of sensor nodes of sending data on the Medium Access Control layer, which can reduce transmission of redundant data and save massive energy. Recent researches show that medium contention among nodes and redundant transmission can be decreased by selection a subset of sensor nodes to transmit data. Therefore, it is a great significance to prolong the lifetime of WSN by designing an energy efficient MAC protocol to filter out redundant data.

So far, researchers have developed many a MAC protocols [3]. But these researches have not applied the characteristics of spatial correlation to design MAC protocol. In this paper, based on the characteristics of spatial correlation in WSN, we develop a novel spatial correlation-based Medium Access Control (MAC) protocol for event-driven wireless sensor networks, referred as SCMAC. SCMAC selects a part of nodes to send data using node selection algorithm, and besides, the protocol adopts collision avoidance mechanism to access the channel. So, SCMAC can significantly reduce transmission of redundant data and save energy.

The remainder of this paper is organized as follows: In section II, we summarize the typical MAC protocols; the circular spatial correlation model is introduced in section III; the detailed description of our protocol is given in section IV; extensive simulation results are discussed in section V; conclusions are presented in section VI.

II. RELATED WORK

In recent years, researchers design a number of MAC protocols for different WSN application. The existing MAC protocols can be roughly classified into three types [4]: contention-based MAC [5, 6, 7], schedule-based MAC [8, 9] and hybrid MAC [10, 11]. S-MAC [5] and T-MAC [7] are typical contention-based MAC protocol. S-MAC aims to reduce the energy consumption by using sleep schedules with virtual clustering. T-MAC incorporates variable sleep schedules to further decrease the energy consumption. DMAC [9] is a schedule-based MAC protocol. It is designed to solve interruption problem and allow continuous forwarding by giving the sleep schedule of a node an offset that depends upon its depth on the tree. DMAC utilizes data gathering tree structure to achieve both energy efficiency and low packet delivery latency. ZMAC [10] is a hybrid MAC protocol. ZMAC can dynamically adjust behavior of MAC between the CSMA and TDMA depending on the level of traffic in the network. When the traffic of

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network is lower, the protocol adopts CSMA. On the contrary, the protocol uses TDMA.

However, these researches focus mainly on the energy-latency tradeoffs. They don't take spatial correlation into consideration without further saving energy consumption. At the same time, there exists some researches to explore spatial correlation in depth [2, 12]. Vuran [12] proposes the spatial correlation-based CC-MAC protocol which gives an Iterative Node Selection (INS) algorithm. INS aims to calculate a correlation radius values. The radius value is broadcast to every sensor node during the network setup. In the first contention phase, the senor nodes are random competition in the wireless channel. Once a node capture the channel, it becomes a representative node in correlation area where only the representative node is allowed to send data to sink, while other nodes turn to sleep. CC-MAC protocol has decreased redundant data and energy consumption. But CC-MAC does not take the signal strength into consideration in the process of sifting the representative node. The way of node selection in the CC-MAC is random resulting in no further efficient saving energy. In this paper, we apply the characteristics of spatial correlation to design MAC protocol. Based on the CC-MAC, we develop spatial correlation-based MAC (SCMAC) protocol. SCMAC protocol which aims to assign higher priority to nodes with high signal strength than nodes with low signal strength when competing channel. The protocol adopts node selection algorithm and collision avoidance mechanism so as to prevent transmission of redundant data. Besides, SCMAC prioritizes the transmission of route-thru packets so that transmission latency in multi-hop is reduced.

III. PROBLEM STATEMENT

For the shortage of CC-MAC protocol that utilizes Random Node Selection Strategy (RS), we adopt Priority Node Selection Strategy (PS) to further reduce energy consumption of network. In this section, we first definite signal strength and introduce a theoretical framework, and then investigate the impact of two kinds of node selection strategies on the reconstruction distortion.

A. Definition of the Singal Strength

In a random deployed WSN, when the event S occurs, the sensor node i will calculate the signal strength of the event source. The signal strength is defined as

$$Z_i = T e^{-\alpha d_i^{\theta}} \quad (\theta > 0) \tag{1}$$

where the T denotes the signal strength of the event source; d_i denotes distance between the node i and the event source; The value of θ derives from the type of the event source; α is used to control the speed of signal attenuations; In (1), it is easy to see that the signal strength of a node decreases exponentially with the distance to the event. Therefore, when the selected node transmits its data to the sink, if the node is far away from the event source, it is not doubt that event information gathered at the sink result in an increase in distortion. In section III-B, We introduce the circular spatial correlation model [13].

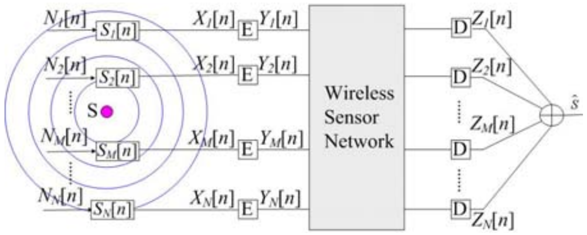

Fig.1 Circular spatial correlation model

B. Circular Spatial Correlation for WSN

Consider that event source S locates in the center of event area. N nodes are deployed in a series of concentric circles. The sink estimates the event source S according to the observation of nodes in event area. In addition, S is modeled as a random process $s(t, x, y)$, which is relate to time t and spatial coordinate(x, y). d_i denotes the distance between the event source S and node i. The node i records event information which is $S_i[n]$, the observation of node i is $X_i[n]$. The node i encode its observation $Y_i[n]$ so that it can transmit encoded information to the sink through the WSN. The sink decodes information to obtain the estimate $\widehat{S}$. The encoder and decoder are respectively denoted by E and D, as shown in Fig.1.

Circular spatial correlation model is different from literature [9], the model assumes that the mean of observation of nodes is nonzero, it indicates that with change of distance from node to event source, observation of nodes will change, which will help the sink accurately estimate event source when the event S occurs.

In Fig.1, once the occurrence of interest event, each observed sample $X_i[n]$ of node i, at time t=t_n is given as

$$X_i[n] = S_i[n] + N_i\,[n] \quad i = 1, \cdots, N \tag{2}$$

where the subscript i denotes the spatial location of node i, i.e.,$(x_i\ ,\ y_i)$; $S_i[n]$ is the realization of the space-time process $s(t, x, y)$ at $(t,x,y)= (t_n,x_i,y_i)$; $N_i[n]$ denotes the noise. $\{N_i[n]\}_n$ is a independent and identically distributed (IID) Gaussian random variables with zero mean and variance σ_N^2 . $N_i[n]$ and $N_j[n]$ are independent for $i \neq j$ and $\forall n$. We only consider the spatial correlation among nodes, the samples are temporally independent. So X_i is given as

$$X_i = S_i + N_i \quad i = 1, \cdots, N \tag{3}$$

where the observation of each node is modeled as IID Gaussian random variables as

$$E\{S_i\} = \alpha, var\{S_i\} = \sigma_S^2 \qquad i = 1, \cdots, N \tag{4}$$

at each point of the event area, the event information S_i is modeled as joint Gaussian random variables as

$$\rho_{(s,i)} = \frac{cov\{S,S_i\}}{\sigma_S^2} = \frac{E\{SSi\}-aa_i}{\sigma_S^2} \tag{5}$$

$$\rho_{(i,j)} = \frac{cov\{S_i,S_j\}}{\sigma_S^2} = \frac{E\{S_iS_j\}-a_ia_j}{\sigma_S^2} \tag{6}$$

Generally, the uncoded transmission is optimal for WSN. According to encoding power constraint P_E, X_i normalized variables as

$$Y_i = \sqrt{\frac{P_E}{\sigma_S^2 + a_i^2 + \sigma_N^2}} X_i, \quad i = 1, \cdots, N \tag{7}$$

In order to estimate the event S from sensed area, for the uncoded transmission, the best method of decoding technique is the Minimum Mean Square Error (MMSE) [14]. Therefore, the estimation Z_i of S_i is the MMSE estimation of Y_i, Z_i is given as

$$Z_i = \frac{cov\{S_i, Y_i\}Y_i + E\{S_i\}E\{Y_i\} - E\{S_iY_i\}E\{Y_i\}}{DY_i} \tag{8}$$

Let $\lambda_i = \sqrt{P_E / \sigma_S^2 + a_i^2 + \sigma_N^2}$, Using (3) and (7) in (8), Z_i can be written as

$$Z_i = \frac{\sigma_S^2(S_i + N_i) - a_i\sigma_N^2}{\sigma_S^2 + \sigma_N^2} \tag{9}$$

Using (1) estimate event S with least squares method, let $E_i = e^{-\alpha d_i^\theta}$. Since T is the estimation of event source, T is given as

$$T = \frac{\sum_{i=1}^{N} Z_iE_i}{\sum_{i=1}^{N} E_i^2} = \hat{S}(M) \tag{10}$$

In order to investigate the impact of selection node with high signal strength to send data to the sink on the reconstruction distortion, in this paper, we assume that M out of N nodes send data to the sink. The distortion achieved by taking advantage of the M nodes to estimation event source S. The distortion is given as

$$D(M) = E\left[\left(S - \hat{S}(M)\right)^2\right] \tag{11}$$

Using (9) and (10) in (11), distortion can be given as

$$\begin{aligned} D(M) = {} & \sigma_S^2 + a^2 - 2\sum_{i=1}^{M} E_i\left[\rho_{(s,i)}\sigma_S^4/(\sigma_S^2+\sigma_N^2)+a\,a_i\right] \Big/ \sum_{i=1}^{M} E_i^2 \\ & + \left\{\sum_{i=1}^{M}\sum_{j\neq i}^{M} E_iE_j\left[\rho_{(s,i)}\sigma_S^6/(\sigma_S^2+\sigma_N^2)+a_j\,a_i\right]\right\}\left(\sum_{i=1}^{M} E_i^2\right)^2 \\ & + \sum_{i=1}^{M} E_i^2\left[\sigma_S^4/(\sigma_S^2+\sigma_N^2)+a_i^2\right] \Big/ \left(\sum_{i=1}^{M} E_i^2\right)^2 \end{aligned} \tag{12}$$

where $D(M)$ shows the event distortion achieved at the sink as a function of the number of sensor nodes M that send information to the sink , correlation coefficients $\rho_{(i,j)}$ between nodes n_i and n_j , and correlation coefficients $\rho_{(s,j)}$ between the event source S from the sensor field and the sensor node n_i. The mean and the variance about signal strength of the event source are denoted by a and σ_S^2 respectively, σ_N^2 denotes the variance of the observation noise; $E_i = e^{-\alpha d_i^\theta}$.

Based on (12), we did an experiment about the impact of two kinds of node selection strategies on the reconstruction distortion in section III-C.

C. Impact of Node Selection Strategy on Distortion

In a 500 by 500 grid, we deployed 60 nodes randomly. We used the signal strength equation with θ=1 and α= (0.03, 0.1). For each value of α we calculated the distortion function (2) by varying the number of sensor nodes that sending information. The simulations were performed in a fixed topology with 1000 trials for each number of representative nodes. The average distortion calculated from these simulations is shown in Fig.2 and Fig.3.

As shown in Fig.2, by using node selection strategies based on RS, the achieved distortion stays relatively when the number of representative nodes is decreased from 60 to 20. This is caused by the fact that the data transmitted is highly spatial correlated.

As shown in Fig.3, by using node selection strategies based on PS, we select the order of representative nodes from high to low according to node's signal strength. It is clear from Fig.3 that the achieved distortion drop fast when the number of representative nodes is increased from 15 to 25. But the achieved distortion rise slowly when the number of representative nodes is increased from 25 to 60. This behavior is due to data sent by nodes with low signal strength.

Comparing Fig.2 with Fig.3, PS achieves a better distortion at the sink using less number of representative nodes. While RS increases the number of representative nodes to decrease the distortion, but the distortion will eventually stabilize when representative nodes achieve a certain amounts. Therefore, PS is better than RS. But, based on PS, representative nodes with low signal strength send data resulting in an increase in distortion. For this behavior, SCMAC adopts a node selection

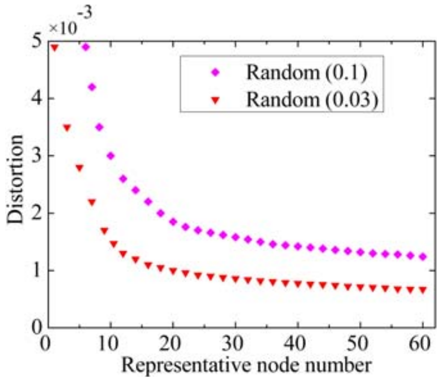

Fig.2 Distortion versus representative node number for RS

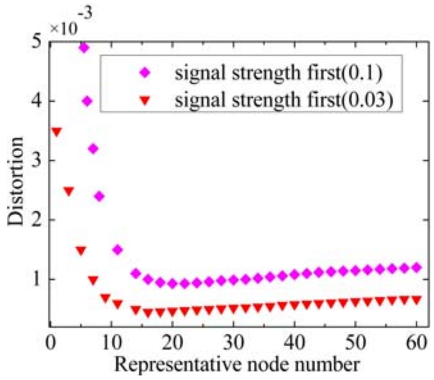

Fig.3 Distortion versus representative node number for PS

algorithm to ensure that *M* nodes with high signal strength successfully send data in a short time and prevent (*N*-*M*) nodes with low signal strength sending data when competing for the shared channel. Where *N* is the total number of sensor nodes in the event area. The nodes will go to sleep state when they can not access the channel.

IV. SCMAC PROTOCOL

Based on section III, we propose a spatial correlation-based MAC (SCMAC) protocol that combines PS with INS algorithm. INS aims to find the number of representative sensor nodes and divide the whole network area into several regions. The region is called as correlation region. The distance of two nodes in correlation region is called as correlation radius (r_{corr}). SCMAC protocol calculates the $\mathrm{r}_{\mathrm{corr}}$ with INS algorithm. In the correlation region, only the representative node sends data to the sink, while others are not allowed to send data. At the same time, the protocol selects node with high signal strength to transmit data so that improves the quality of data with PS. In this section, we introduce the packet structure, node selection strategy and procedure of protocol implementation in detail.

A. Packet Structure

In order to pack the information of node priority and spatial correlation, in the reserved space of packet structure, a bit is used as one new field called the Type of Packet(TP) Field, while 16 bit is used as another new field called Priority Sending (PS) Field as shown in Fig.4. TP field is used to distinguish the type of packet. The node performs source sending operation or router forwarding operation according to the type of packet. PS field saves value of transmission probability of node, which determines the selection of representative node.

- *Source Sending Operation*: Source nodes transmit their generated packet to the sink.
- *Router Forwarding Operation:* Nodes receive packet from other nodes, and forward the packet to next hop.

Once the node detect occurrence of the event *S*. the node sets TP field of DATA and RTS packets to 1. It indicates that this packet is source packet. When one node listens to the packet, the node checks the value of TP field of RTS packet. If the value is 1, the receiver thinks that the type of packet is source packet and set the TP field of CTS packet to1, then the receiver sends the CTS packet back to source node. Hence, each neighbor of sender and receiver has known the type of packet. When a node receives the DATA packet, it sets TP field of the packet to 0, indicating that the packet is route-thru packet. Then the node forwards the packet to next hop. The detailed transmission of route-thru packet is introduced in section IV-D.

RTS Packet Structure

	Frame Control	Duration	RA	TA	TP	PS	FCS
bits	16	16	48	48	1	16	32

CTS Packet Structure

	Frame Control	Duration	RA	TP	FCS
bits	16	16	48	1	32

DATA Packet Structure

	MAC Header	TP	Frame Body	FCS
bits	240	1	0-18496	32

Fig.4 Structure for RTS, CTS and DATA packet

B. Representative Node Selection Algorithm

In order to effectively filter out the redundancy, we assign high priority to nodes with high signal strength while contending for the channel. The node selection algorithm is given as

1) When a node in the event area has detected the occurrence of an interested event, whether it is necessary to send its data depends on its signal strength *Z*. For easy computing, we propose an even stair function *f* (*Z*) which maps signal strength of node to *a*. As shown in Fig.5, when the value of *Z* is larger than $Z_{max,}$ then *a* equals 1; when the value of *Z* is smaller than $Z_{min,}$ then *a* equals 0.

2) We use a node selection algorithm of time slot of non uniform probability distribution to decide priority of transmission of each node [15]. The node with high signal strength has higher probability to select fore time slot while node with low signal strength has higher probability to select back time slot. The probability distribution function of transmission of each node in each time slot is given as

$$p(c)=\lambda\left(\frac{1}{1+e^{-a(c+1)}}-\frac{1}{1+e^{-ac}}\right)\ \ \alpha=f(Z),c\in[1,CW] \tag{13}$$

where *p* is the function of $\alpha(0\leq\alpha\leq1)$, *c* denotes time slot, λ

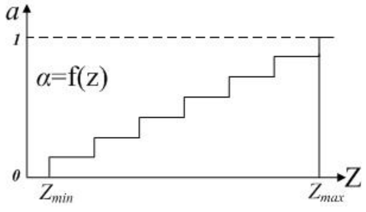

Fig.5 Z versus *a*

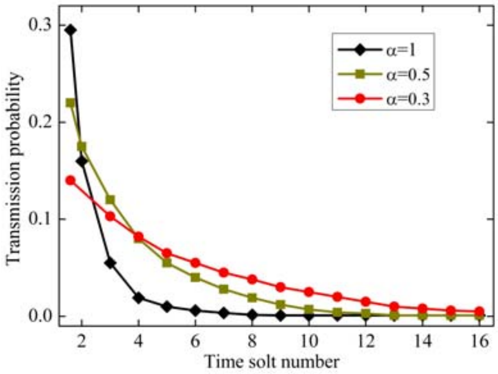

Fig.6 Transmission probability versus back-off time slot number

is a constant. Fig.6 describes the impact of a on probability of transmission for each slot. Horizontal axis denotes slot number. Vertical axis denotes probability of transmission of each node.

It is easy to see from Fig.6 that the probability of transmission of nodes increases with the value of a increasing. Hence, it is easy to achieve that nodes with high signal strength have higher probability to send their data. When the node's signal strength Z is smaller than Z_{min}, the node has less probability to send its data. Hence, once a node finds it doesn't need to send its data, it will switch to sleep state for some time. During sleeping, the node turns off its radio, and sets a timer to awake later.

As explained above, the probability of transmission of each node depends on signal strength. We may decrease the value of Z_{max} to reduce the distortion. At the same time, the appropriate value of Z_{max} and Z_{min} can prevent a great number of nodes sending data as so to reduce energy consumption.

C. Collision Avoidance Mechanism

Though having been dramatically reduced among the nodes with low signal strength, the contention collisions do still exist among the nodes with high signal strength. In addition, since those nodes have large probability to send data leading to excessively consume the energy. It is detrimental to balance network energy consumption and prolong the network life span. In order to further reduce collision and balance energy consumption in the process of accessing wireless medium, map residual energy of node E to l, as shown in Fig.7.

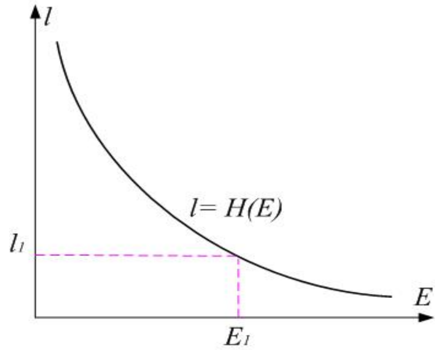

Fig.7 E versus l

We design a random back-off function τ (α, l). The function is given as

$$\tau\left(l,\alpha\right)=\frac{\lambda}{l2^{\alpha}} \tag{14}$$

where l denotes parameter of node's residual energy, λ is a constant. a is predefined function $f\ (Z)$ which maps signal strength to a back-off time slot. As shown in (14), the larger a and l, the shorter the back-off time. So nodes with high signal strength and more residual energy have higher probability to transmit data. If nodes with high signal strength and less residual energy contend for the channel, the back-off time will become relatively longer resulting in nodes having less probability to access the channel. But the energy consumption of nodes is decreased, which can balance the network energy consumption. Hence, after each node gets the chance to transmit its data, it chooses a back-off time τ. It will ensure that contention collision is minimized, and the node with high signal strength and more residual energy has higher probability to transmit its data. At the same time, it will prolong the network lifetime.

D. Procedure of SCMAC Protocol

SCMAC protocol aims to filer out redundant data by using PS and INS algorithm, and prioritize transmission of route-thru packet to the sink. Source packet and route-thru packet access the channel as follow:

1) *Source Packet Local-access the Channel:* In the network initialization phase, the sensor nodes transmit their data to the sink for the duration t. Each node calculates the probability P and back-off time τ according to observation of nodes. The protocol performs INS algorithm to obtain value of correlation radius, the value is broadcast to every node. The nodes start to contend for the channel. In the first contention phase, all nodes with event information use RTS/CTS/DATA/ACK structure to contend for the medium. Each of these nodes set PS field of RTS packet to contend for the channel. When neighbor node receives the packet, and then the node compares the value of PS field of RTS packet with its own. If the value is lager than its own, the neighbor node gives up contending for the channel. On the contrary, the neighbor node will continue to contend for the channel. At this time, the protocol will perform the back-off function.

At the end of first phase, once the node i captures the channel, it becomes a representative node of its correlation region determined by correlation radius. It continues to send information to the sink. When other node j hears the information and estimate its distance $d(i,j)$ to node i. If the $d\ (i,j)$ is smaller than r_{corr}, the node j consider that node i is its correlation neighbor. The node j will defer sending data. Otherwise, it will continue to contend for the medium.

As we have known above, in the correlation region, the representative node is allowed to send data to the sink. In order to save the energy consumption, other nodes go to Sleep State (SS) of duration T_{SS}. During the SS period, correlation neighbor starts to monitor channel after a random time T ($T < T_{SS}$) in order to keep the network connectivity. If correlation node receives RTS packet, then it switches from the SS to receive state and transmit data. If the correlation node doesn't receive the packet for some time, the nodes go to sleep again. After the duration T_{SS}, representative node leaves the channel to other nodes.

2) *Route-thru Packet Multi-hop-access the Channel*: As a representative node transmits its packet to the sink, the packet is forwarded by intermediate nodes in sensor fields where may transmit its own generated data packet. However, since the redundant data has already been filtered out in the local area, the route-thru packet must be given priority over the packets generated in sensor fields. Hence, we use a priority strategy to forwarded route-thru packet as follows: When a correlation neighbor receives an RTS packet during the listening period, it checks the value of TP field of RTS packet, if the value is 0, regarding that the packet is route-thru packet. So it receives the route-thru packet and forwards it to the next hop. During the transmission, the representative node can not send its information until the route-thru packet is forwarded completely. SCMAC protocol uses greedy algorithm [16] to select the receiver node in order to ensure that the node of next hop is the nearest to the sink. SCMAC repeatedly executes the above process so that the multi-hop transmission of the packet can be accomplished in time, as shown in Fig.8.

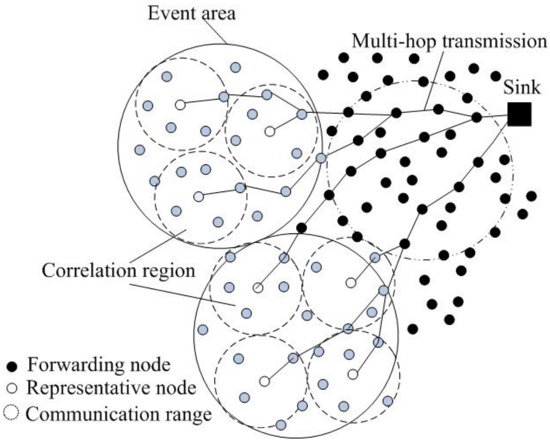

Fig.8 Multi-hop transmission of the packet

V. SIMULATIONS RESULT AND ANALYSIS

In order to verify performance of SCMAC, S-MAC and CC-MAC, we use *OMNET++* for us simulations. We first give the simulation parameters, and then analyze simulation results.

A. Performance Metrics and Simulation Parameters

Based on circular spatial correlation model, we mainly verify the following performance metrics.

- *Distortion: it is given in (12).*
- *Average Energy Consumption:* it denotes the average energy a sensor node consumes during the simulation.
- *Medium Access Delay:* it denotes the average time spent between the time a packet is handed to the MAC layer and the time it is received at the next hop.
- *Packet Delivery Rate:* it denotes the ratio between the total number of packets received at the sink and the total number of packets generated by all nodes.
- *Packet Drop Rate:* it denotes the ratio between the number of dropped packets during the medium access and total packets sent from MAC layer.
- *Network Life-cycle:* it denotes the survival time of network nodes.

The simulation is performed in a 500*m*×500*m* field where 60 nodes are randomly deployed. We assume assigning a node as the sink and all other nodes send their event information to that sink. In each simulation, event source is located at the center of event area. In order to investigate the performance of protocol proposed, different traffic load is produced by varying the reporting interval of each node. Each simulation is performed for 1000s. Simulation parameters are given in TABLE I.

TABLE I SIMULATION PARAMETERS

Parameters	Sizes
Network areas	500×500m^2
Transmission range	100m
Packet length	100bytes
Bandwidth	20Kbps
Transmission power	24.75mW
Receiving power	13.5mW
Sleeping power	15uW
Listening power	13.5mW

B. Result Analysis

Simulation results are illustrated in Fig.9 to Fig.14. The energy consumption performance of SCMAC with other energy-aware protocols, CC-MAC and S-MAC is shown in Fig.9. It is easy to know from Fig.9 that SCMAC has significant energy conservation compared to S-MAC with the help of spatial correlation-based approach. The developed SCMAC also consumes about 35% less energy compared to CC-MAC protocol because of less number of nodes contending for the channel.

Fig.10 shows the medium access delay achieved by each MAC protocol. CC-MAC performs very close to SCMAC with medium access delay about 0.05s. It is clear from Fig.6 that CC-MAC and SCMAC have increased the medium access delay compared to S-MAC, which is consumed by the process of sifting representative node. Note that, the delay performance of three protocols is relatively constant for variable traffic load.

The packet delivery rate of SCMAC is shown in Fig.11 along with CC-MAC and S-MAC. It is clear that SCMAC achieves higher packet delivery rate compared to CC-MAC due to further reduce transmission of redundant data. S-MAC achieve low packet delivery rate compared to other protocols, which is due to the increase in collision when contending for the shared channel.

The packet drop rate of SCMAC protocol is shown in

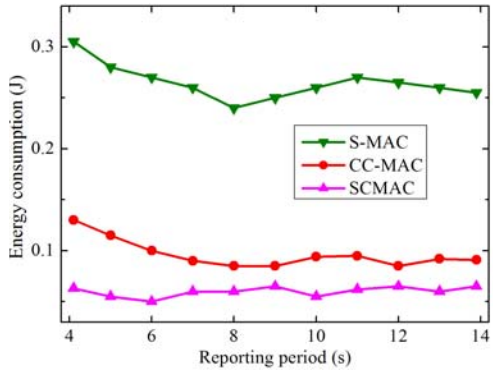

Fig.9 Energy consumption versus reporting period

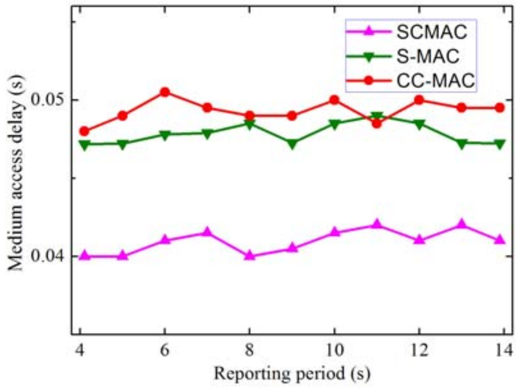

Fig.10 Medium access delay versus reporting period

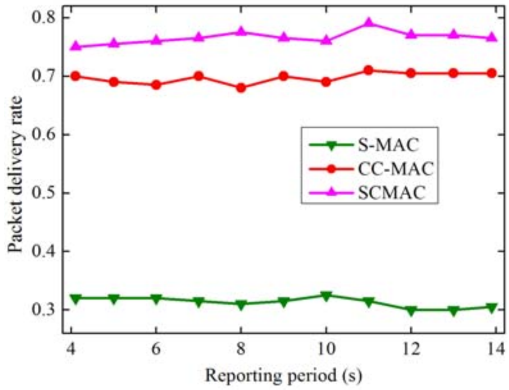

Fig.11 Packet delivery rate versus reporting period

Fig.12. Comparing with S-MAC and CC-MAC protocol, SCMAC protocol has lower packet drop rate. Because it has smaller data transmitted than CC-MAC in the network, which further filter out the redundant data and reduce contention for the channel. It is clear that the packet drop rate of SCMAC is dramatically lower than S-MAC. This is caused by in fact that, in dense WSN, S-MAC has not taken spatial correlation into consideration.

It is easy to see from Fig.13 that network life-cycle of SCMAC protocol is longer than other MAC protocol achieving up to 700s, while S-MAC achieves 200s. This is because S-MAC don’t take the spatial correlation into consideration, the massive energy is consumed in collision when contending for the shared channel. So the lifetime of S-MAC is shorter than other protocols. Comparing with CC-MAC, SCMAC adopts collision

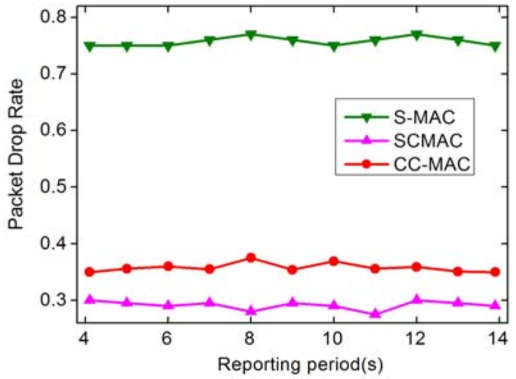

Fig.12 Packet drop rate versus reporting period

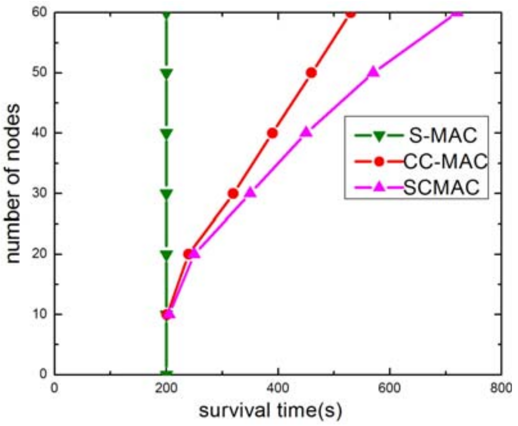

Fig.13 Number of nodes versus survival time

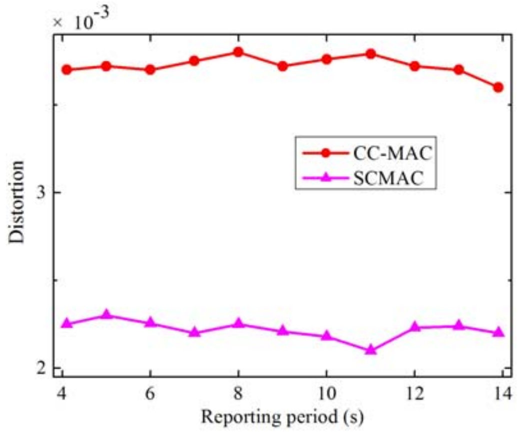

Fig.14 Reconstruction distortion versus reporting period

avoidance mechanism to further reducing collision and balance the energy consumption of network. Hence, SCMAC further prolongs the lifetime of network.

Fig.14 shows the achieved reconstruction distortion of SCMAC and CC-MAC. SCMAC achieves lower distortion (about 40%) than CC-MAC, which follows from the fact the sensing quality is taken into consideration in the process of sifting representative nodes.

VI. CONCLUSIONS

In this paper, in order to prolong the lifetime of WSN, we investigate the ways of selecting sensor nodes and propose a spatial correlation-based energy efficient

SCMAC protocol. SCMAC utilizes priority node selection strategy to filer out redundant data. Through this way, energy consumption of network is reduced. In addition, by utilizing collision avoidance mechanism, the collision in the process of accessing channel is dramatically decreased. Simulation results show that our protocol achieve higher performance than CC-MAC in the aspects of energy consumption, transmission latency, packet drop rate, packet delivery rate, network life-cycle and reconstruction distortion.

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