The Design of Multi-channel Token Assignment Protocol Based on Received Signal Strength Indication*

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Abstract. This paper presents the multi-channel token assignment protocol for the wireless sensor network based on received signal strength indication. Communication cycle is divided into several specific functional windows to received signal strength indication as the terminal node credentials for channel reservation and to reduce the overall network access competition and data collisions. At the same time it extends the node sleeping time, so the energy will be saved and prolong the life of the network will be obtained. Making use of dynamic channel assignment methods can improve the utilization of multi-channel, avoid packet collision and improve the network throughput.

Keywords: WSN, Token, Multi-channel.

1 Introduction

Wireless sensor network is self-organizing communication networks composed by a large number of wireless sensor nodes. The important function of wireless sensor networks is transmitted the physical data collected to receive points through the wireless network to facilitate data analysis and monitoring. Because of the vulnerability and interference of wireless sensor networks, when a large number of sensor nodes send data to the receiving node, it will inevitably lead to mutual interference, sending conflict, large number of network packet loss, data distortion, additional overhead and so on. Many studies show that the energy consumption used in the wireless sensor network for communication is much higher than using the CPU and other circuit energy[1]. Additional retransmission burden reduces the life cycle of wireless sensor network node, thus affecting the normal operation of the network and even cause network paralysis.

In our long-term monitoring study for cows estrus, wireless sensor networks is applied nodes deployed densely and data transmission volume environment. Therefore, to design an efficient multi-channel communication protocol is extremely important. It can minimize energy consumption of wireless sensor nodes under the

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premise of supporting the network normal communication. Therefore it can prolong the wireless sensor nodes' working time and entire network using life[2].

2 Technical Background

Multi-channel communication technology for wireless sensor networks is one of research focus in the current. Through separating communication channels between various nodes can effectively prevent crosstalk and data collision problems under a single channel. So that it increases network capacity and extends the network lifetime[2].The key for achieving Multi-channel communication technology in wireless sensor network is the design of MAC layer protocol. To promote the standardization and industrialization process of sensor networks, the industry developed the IEEE802.15.4[3], Zigbee[4] and other protocol specialized applications for wireless sensor network. In the current existing network protocols, the other MAC protocols have been using CSMA / CA method of single-channel communication mode in addition to IEEE802.15.4 protocol to support multi-channel communication,. Through monitoring the channel energy and RTS / CTS packet exchanged avoids packet collision in channel. Different nodes achieve control power of the channel through competition[5].

There are several keys for achieving multi-channel MAC protocol in wireless sensor network. As follows:

(1) Channel assignment and switch mode.

In the wireless sensor networks which support the multi-channel, efficiently assignment of channel resources, maximize efficiency and communication capacity of the network, is an important research topic. At present the models of channel assignment are as follows: fixed channel assignment, the assignment of same frequency hopping, phase channel hopping assignment and dynamic channel assignment based on coloration problem[6].

(2) Channel access mode.

The same as single channel network, after obtaining access to communication channel at the node, you need to follow certain access rules to access the network. At present channel access mode are as follows:

The mode based on channel Carrier Sense and competition access has the advantages like simple, without time synchronization and scalability well. But more energy will be needed

The mode based on TDMA which avoids the collision and carrier sense under competitive access mode. But it is difficult to ensure that each node can be assigned to a non-collision time slot.

The mixed-mode based on CSMA / CA and TDMA seeks to combine their advantages and avoid their shortcomings. But design complexity is higher[5].

(3)Node Coordination and found technology.

Node Coordination and foundd technology belongs to supporting technology for multi-channel MAC layer protocol. Control node's main task is unity the space of all common nodes, accepts applications for channel access, and distributed communication channel according to certain rules. The main node found means have active and passive. The active found is waking up the sleep node periodically and actively send a confirmation signal to the control node to justify their existence. The network control channel can be omitted under this mode. The passive found mainly refers that common control node reports own status after receives wake-up signal from control node. This mode generally requires a dedicated control channel to send control frames.

3 The Design Framework of the Multi-channel Token Protocol

This paper presents a multi-channel token assignment protocol based on receiving signal strength (RSSI), and it improves the node energy utilization and network throughput in the communication process. At the same time it can also reduce the energy consumption and prolong the life of the node and network.

3.1 Protocol Objects Description

(1) Terminal node. It is node concrete realization network function with sensor, in order to realize the wireless network inherent perception function. In our protocol terminal node is sensor node installed on the bulls' body. It has dormancy, detection, and activity three states These three states switching among each other under the interference of the internal timer and control node. Terminal node controlled by control node, according to its information, sends communication channel using request to control node. And then it will obtain transfer data token under a unified dispatch by the control node. After accessed token, terminal node will be switched to the corresponding communication channel and transmit data to communication node. This protocol allows exist multiple terminal node and they are battery-powered.

(2) Control node. Control node acts as an intermediary in the protocol. It works in control frequency and its main job is synchronization time of communication nodes and every terminal node within the scope of communication range and controlling terminal node into channel application process. It also monitors communication node state, records communications channel's situation like free or busy, accept terminal node channel application and execute the corresponding algorithm to transmit communications channel token to terminal node. Last it assigns and activates corresponding free communication node. Control node works only in control frequencies. This protocol only allows one control node exists. The control node are battery-powered

(3) Communication node. Each communication node works in two channels. One is controlled channel, and when there is no transmission data the communication node reports itself to control node through control channel. Another is data communication channel. Each communication node has a unique data communication channel. Control node can obtain Status like busy or free of the corresponding communication channel according to communication node. Communications nodes at receiving control node's activation information, it will switch to own communication channel and communicate to the terminal node with token. This protocol allows many communications nodes and communications nodes uses battery-powered.

3.2 Achieving Basis

The design and implementation of communication protocol is based on existing hardware and practical conditions. They are as follow:

(1) wireless transceiver module has the ability of half-duplex multi-channel wireless communications. Wireless network nodes in the protocol include the wireless transceiver module used by terminal node, communication node and control nodes. All of them need to have half-duplex multi-channel communications capabilities so that they can switch from one working channel to another and switching between the various working channels does not overlap. Meanwhile in every working channel, the wireless transceiver module works under half duplex mode. The CC2500 wireless transceiver module used in this system has this capability.

(2)Wireless transceiver module has the ability of detection the strength of RSSI. Under the receiving state, the wireless transceiver module of the node can detect the wireless signal strength of the current environment and expressed that in units of dBm. In this protocol, the terminal node estimates little distance between itself and the control node by RSSI value. The CC2500 wireless transceiver module used in this system has this capability.

(3) The timing accuracy of built-in clock in the Wireless network is less than 1 ms. To coordinate the pace of each terminal node, a timer is necessary and the timing accuracy should be less than 1 millisecond. In this system, the node's MCU uses MSP430 series processor, which has the highest speed up 400KHz internal timer and the minimum period 2.5 microseconds.

(4) Channel switching time of wireless network nodes is less than 100 microseconds. Channel switching time is the guideline of wireless module hardware delay and will directly affect the protocol performance and network capacity. Channel switching time less than 100 microseconds can better ensure the needs of protocol performance.

(5) Multi-channel is divided into a number of communication channels and a control channel. Communication channel only transmits data packets and control channel only transmits control packets.

(6)Between the terminal node and control node is called single-hop communication. Under this application scenario, the cattle get into the access point communications area only needs a short time, so that the node should give priority to transmit its own data rather than as a relay node in the routing of other nodes. Nodes may withdraw at any time control node's communication area. If as the routing, it will easily lead to communication failure. This protocol requires the node assess the distance to the access point. If multiple routes is used, distance estimates will be too complex and difficult to manage.

3.3 Condition of Hypothesis

Before the multi-channel token assignment protocol is proposed, some assumed conditions in wireless sensor network realistic environment should be given in this section.

(1)The communication mode between terminal nodes and control nodes is single hop. The wireless communication signals which takes the control node as the center can cover the whole monitoring area. As long as the terminal node enter the communication region, it will monitor the data packets from the control nodes and the RSSI value can be get

(2)AS the distance between communication nodes and control nodes is short, the RSSI value between terminal nodes and control nodes can be considered equaling to the RSSI value between terminal nodes and communication nodes. It can use the RSSI value which is drawn from monitoring the control nodes to substitute the RSSI value which is from the communication nodes, and further acquisition is not needed.

(3)Terminal nodes enter the communication region to transfer signals, and the whole monitoring region is under the non-interference communication environment. The control packets and data packets can be transferred reliably.

3.4 Protocol Framework

Wireless sensor network nodes enter the communications monitoring area randomly, breaking the traditional cluster structure and transfer form. Free dynamic access network can realize efficient and fair acquisition to the channel token, stable and reliable data communication. According to the traditional access protocol based on TDMA and the access protocol on Multi-Channel, we design a communication model. Taking the control node as the center of a circle, it divides the communication region into some concentric intervals, as shown in figure 1. Each interval respectively represent period of communication signal strength band segment. The control nodes can be seen as the coordinate node of the Multi-channel token assignment protocol to manage the communication of the nodes in the monitoring region. After a terminal node obtain the communication token, it occupies a communication channel exclusively to transfer data reliably and credibly. This control node can be called gateway node.

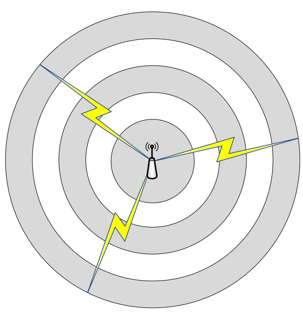

Fig. 1. communication region division

Energy consumption is undoubtedly the first considerable question in wireless sensor network. In communication region, it borrows ideas from TDMA to realize intermittent work cycle, reducing the loss and waste of the terminal node energy. Each terminal node works according to certain cycle, and the work cycle divides into dormancy period and activity cycles. In the communication monitoring region, the control node which is power-supply, radioes synchronous signal frame repeatedly, starts channel assignment scheduling cycle, not considering the energy loss. Through this framework, it can extend the dormancy and network lifetime goal of the node. As shown in figure 2, the assignment scheduling cycle divides into communication period and scheduling period. Each communication period is composed of four windows, synchronized signal window, detecting window, reservation window and assignment scheduling window. The scheduling period is after the channel detecting window and the channel reservation window. According to the obtained channel information and reservation information ,it dose the scheduling calculation and radioes the result in the next channel assignment scheduling window.

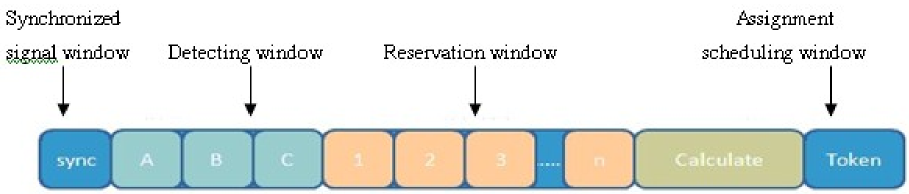

Fig. 2. Assignment scheduling cycle

(1)In synchronized signal window, control node broadcasts synchronous signals to the communication nodes and terminal nodes, noticing a new channel assignment cycle;

(2)In channel detecting window, free communication nodes report the current state to control node;

(3)In channel reservation window, terminal nodes can detect the RSSI value from itself to the control node by the signal synchronous data packets so that it can obtains its signal strength frequency band. It issues a reservation request in the corresponding reservation window.

(4)In channel assignment scheduling window, control node broadcast the scheduling result to all the nodes of the network. It specifies a terminal node to obtain the communication token. The node combines the corresponding communication nodes, switches to the corresponding channel together and transfers data.

After the network is divided into several non-overlapping signal strength interval, each terminal node locates the corresponding reservation period in channel reservation window according its signal strength interval, and calculate the dormancy cycle and activity cycle. In the activity cycle, it realize the efficient data communication, avoiding unnecessary network request and waiting and reducing the mutual interference. Once the terminal node obtains channel token, it switches to a specific channel exclusively, avoiding the outside interference and reducing the extra expenses which are brought by unnecessary packet loss and retransmission. Communication period defines as the period that the nodes communicate in synchronous information and control information. It is also called meeting time for nodes. The communication between the nodes should be finished on control channels.

4 Protocol Description

After the communication region which takes the control node as center is established, the whole wireless communication region repeats channel assignment scheduling cycle, started by the control node. Synchronous signal issued by the controlling node, is seen as a logo which starts a scheduling cycle. Synchronous signal covers the whole communication region. The states of terminal node states include dormancy, detection, activity. In order to save the energy consumption, terminal nodes are general dormant, start into detecting state periodically. In detecting state, terminal nodes open wireless transceiver and adjust to the controlling channel, detecting the synchronous information of the controlling channel. If it has not received any synchronous signal, it indicates that there is no terminal nodes in the communication region, and re-enter the sleep state. If synchronous signal is received, it indicates that terminal nodes have entered the communication region, and become active immediately. According to the RSSI value, it locates the period corresponding to the channel reservation window, defines the schedules in this assignment scheduling, sets the start time to coordinate the switching of the controlling node states.

4.1 Signal Synchronous

After terminal node detects the synchronized signal the first time, it considers the synchronized signal as a switching signal, and transforms into active state. Terminal node does not participate in the channel assignment scheduling cycle. According to the content of this synchronized signal, it identifies the start time of the next channel assignment scheduling cycle, sets the wake-up clock, and is dormant again. It wakes before the next synchronized signal, participates channel assignment scheduling cycle formally. Terminal node schedule is strict to the dormancy cycle and activity cycles of this protocol, ill the communication token is obtained and the communication finishes. And after terminal node converts to active state, it records the current time of the terminal node, and takes it as start time. In the later calculation process, it calculates out the waiting time of requesting communication token according to the start time.

Channel assignment scheduling cycle begins with synchronized signal window. The active nodes wakes under the control of inner start time, open the wireless transceiver adjusting to control channel, and detects the synchronized information of the controlling channel. Meanwhile, control node in this window time broadcasts synchronized signal packets through the controlling channel. Synchronized signal is composed of {[packet type], [the number of communication nodes],[the number of RSSI band], [the number of time gaps],[checksum]}. Since each communication nodes shares a communication gap in the channel detecting window, it reports its state of corresponding channel to the control node. Therefore, the number of the communication nodes equals to the time gaps in the channel detecting window, terminal nodes can obtains the specific time width of the channel detecting window according to the number of the communication nodes. In addition, each RSSI band occupies a period in channel reservation window. Terminal node can calculate out the specific time width of the channel reservation window, according to the number of communication nodes, RSSI band, and time gaps in the synchronized signal packet.

Each terminal node can also define the RSSI value according to the synchronized signal strength. It can also define its reservation period in the channel reservation window according to the band of the RSSI value. Thus, it can set the start time of the next communication cycle accurate. Communication nodes who receive the synchronized signal just need to wake up according to the channel detecting window provided by the protocol, and report its state to the control node. It obtains the RSSI value to the controlling node, according to the strength of the received synchronous signal.

4.2 Channel Detection

In the window of channel detection, control node monitors the data packets from communication channel by transferring to receive status. This protocol divides the window into sever time slots, the number of which is equal to that of communication nodes. The time width of time slot is standardized by the practical situation of communication area. Every communication node has its own time slot on the basis of its ID. The smallest ID will be distributed the first time slot, conversely, the biggest one will be distributed the last time slot.

Because the communication nodes are fixed around the control node, and the quantity of communication nodes is artificially controlled, so there is not much change. Every communication node can conjecture its distributed time slot by means of obtaining the initialized information at the time of setting up the communication area. At the same time, the time width can be determined on the basis of the practical energy consumption and the performance parameter of specific transceiver. In order to reduce the overhead of the control information, the sequence of time slot every communication node obtained is regarded as its identification code in the communication area. Every communication node keeps one list, while the form of all records in this list is {node ID, time slot number}, realizing the mapping between communication node ID and time slot number.

All the communication nodes work in one of the control channel or communication channel. If the communication node is distributed to communicate with some terminal node by control node, the communication node will transfer into communication channel.

Communication node can not monitor the synchronizing signal of control node, and also can not send data to control node in the window of channel detection when communicating. Only the unoccupied communication node can transfer to control channel, and send the channel information to control node through the control channel in its time slot. While the terminal nodes don't participate the works of channel detection, closing the whole channel detection window and maintaining the wireless transmitter in sleep state can similarly reduce the energy consumption.

Because in the channel detection window, the reported data packets only indicate the communication node and its corresponding communication channel are in idle condition, the communication nodes which don't report data packets are regard as in busy state, the contents of data packet only need several bit status information.

Similarly, because the communication node IDs and the time slots of channel detection have the one to one relationship, control node can also conjecture the ID of communication node and don't send node ID any more by the means of the time slot due to the reported data packet, which reduces the sent amount of information by leaps and bounds, and alleviates the load of wireless network.

4.3 Channel Reservation

Enter into channel reservation window after channel detection window. Set up buffer mechanism in the control node, and record all the terminal node IDs and waiting time, the terminal nodes which have sent reservation requesting don't participate in this channel reservation and keep sleeping mode, in order to refrain from repeatedly applying and causing channel jams, this kind of terminal node only need to be awakening in the dispatching window and waiting for dispatching. While control node keeps accepting state to monitor the data packets from other terminal nodes in communication channel.

The same as channel detection window, this protocol divides the window into several reservation time intervals, the number of which is equal to the number of RSSI frequency band. Every terminal node determines the corresponding reservation time interval on the basis of frequency band its RSSI located in. Every time interval of channel reservation window has some time slots, in order to solve the access conflict of terminal in the same time interval. While the number of reservation time interval time slots and the time width should be determined on the basis of the practical energy consumption, the performance parameter of specific transceiver and the network capacity.

In the channel reservation window, the number of reservation time intervals is equal to the number of RSSI frequency band. There are several strategies of dividing the RSSI frequency band in communication area. In this protocol, control node is regarded as the centre of communication, the RSSI frequency band is divided into some concentric circles, the length of every interval is equal to the body length of a grown cattle, Fig.03 shows. While the value of RSSI of every interval is integrated into the same RSSI frequency band. The number of channel reservation window time intervals n=the length of radius of communication region/ the body length of a normal cattle.

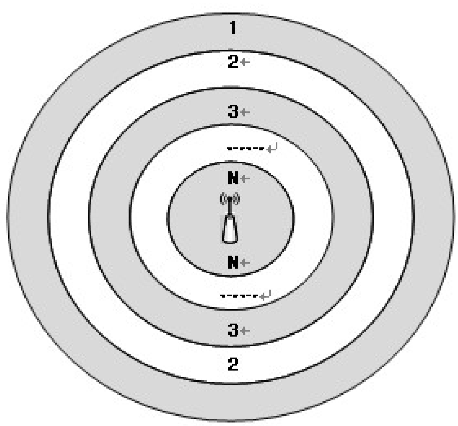

Fig. 3. Partition of concentric circles intervals in communication area

Because at the same time of receiving the signal synchronization packets, terminal node is monitoring the RSSI value which itself leaves from the control node, the number of communication nodes and the number of RSSI frequency band. So, terminal node can accurately figure out the time interval in which it should be awakened.

The terminal node transfers into control channel after being awakened, and sends the reservation requesting packets at the first time slot in the reservation time intervals. Because all the terminal nodes in the same concentric circles interval are in the same RSSI frequency band, while the RSSI frequency band and the reservation time interval have the one to one relationship. Therefore, in the same reservation time interval, there can be multiple terminal nodes send reservation requesting packets to control node and cause access conflict.

For the sake of access fairness, this protocol is based on the thinking of CSMA backoff algorithm, when the first time slot in reservation time intervals takes place access conflict, every terminal node will have a certain extent time delay in the following reservation time intervals. The terminal nodes which have delayed should send reservation requesting packets again， in order to avoid conflict risks. While after receiving the requesting packet, the control node return to terminal node a ACK acknowledge signal, confirming the reservation successful. The terminal nodes which don't receive the ACK acknowledge signal are deemed to be interfering with other terminal nodes, and requesting is failed, if it is still be failed after backoff access, then the terminal node should quit this dispatching cycle and enter into sleeping state again. If this terminal node is awakened before the next synchronizing signal is coming, it still can participate in channel dispatching cycle.

Channel reservation requesting packet is comprised of {[packet type],[symbol information],[terminal node information],[check sum]}. Terminal node information includes the ID of terminal node, terminal node records the start time when receiving the first synchronizing packet. The terminal nodes which have sent the reservation requesting packet enter into sleeping state again, and awaken in the channel dispatching window ,receiving the token applying result of control node broadcast.

After the channel detection window and the channel reservation window, control node has received the information of idle channel in the communication area and the reservation requesting information of all the terminal nodes, and starts to dispatch the channel and resource, calculate the channel dispatching, and broadcast the results in the communication though the channel dispatching window.

4.4 Channel Dispatching Calculation

After the channel detection window and the channel reservation window, the following step is dispatching period, control node starts to conduct the channel dispatching calculation by the receiving idle channel information and the reservation requesting information. If the number of reservation requesting is smaller than the number of available channel, dispatching channel is simple, control node can select randomly idle channel for the terminal nodes which have sent the reservation requesting information. However, when the number of reservation requesting is larger than the number of available channel, it needs to dispatch and calculate the reservation requesting information, and get results of dispatching. Because dispatch calculation needs to be completed under limit time, so the time complexity of this algorithm can not be too high.

Because of the start time of every terminal node in the requesting packet, this start time is the system time that recorded by terminal node when entering into the communication area and transferring to active state. Control node can calculate the waiting time of communication token of various terminal nodes. At the same time maintaining a priority buffer queue by the means of the length of waiting time. Control node will allocate preferentially channel recourse to the requesting node who has high-priority, and render the requesting nodes who has not obtained channel recourse to keep in the buffer queue. For the following reservation requesting, control node place it into suitable location in the buffer queue by the waiting time of the terminal node.

The whole channel dispatching calculation figure out the waiting time of requesting communication token of all the terminal nodes, by the means of which, control node maintains a priority buffer queue for the token dispatching use.

4.5 Token Assignment

When scheduling calculation ended, it enter the channel assignment scheduling window, all nodes wake up under the control of their inner timing clock and still work on the controlling channel, monitoring and preparing to receive the channel scheduling packets which are sent by controlling nodes.

According to the priority scheduling buffer queue which is obtained by channel assignment scheduling calculations, controlling node selects the team head node. It sends probing packets to terminal node to enquire the current state. When the terminal node receives the probing packet, it feedbacks its current state to the controlling node. Feedback data packet is composed of {[Packet type], [Flags], [Current RSSI band], [Checksum]}. Current RSSI band refers to the RSSI value which is detected from the synchronous signal packet. The packet begins with the current channel assignment scheduling cycle. Flags are used to describe whether terminal nodes are quitting from communication region. After the RSSI value is detected, terminal nodes map it to the corresponding RSSI band. When a terminal node goes through the communication region and the RSSI band experience from weak to strong, from strong to weak. When terminal node detects the current RSSI band is weaker than the last record, it indicates that the node is quitting from the communication region and the flag is set to "1",otherwise set to"0".

Controlling node determine whether to distribute the communication token according to the state from the feedback of the terminal node. If the communication node is quitting the region and the RSSI band is too weak, its assignment qualification will be cancelled. It takes out the head node from the priority scheduling buffer queue to continue the inquiry. Until the terminal node which meets the requirements is find, it broadcast signal scheduling controlling packets. Channel scheduling controlling packet is composed of {[packet type], [communication node ID], [terminal node ID], [communication channel ID], [additional information], [Checksum]}. When the terminal node and the communication node receive the scheduling controlling packets ,it switches the wireless transceiver to a specific communication channel according the channel assignment information of the scheduling packets, starting to communicate. As there is a certain time limit in channel assignment scheduling window, this method exist certain risk. Therefore, channel assignment scheduling window ends in strict accordance with the provision of the protocol. Even when the window ends, idle channel has not been distributed out, it will be reserved for the next channel assignment scheduling cycle.

4.6 Data Communication

Terminal node allocated communication token quits the channel assignment scheduling cycle, and exchange data with the designated communication node in designated channel directly. After the terminal node completes the exchange, it closes the wireless transceiver immediately and back to dormancy, while the communication node switches to controlling channel, and enters the channel assignment scheduling cycle. If the terminal node can't allocate the channel resource, it continues to wait.

The node has no fixed channel resource in this protocol and it allocates channel resource dynamically according to the reservation information of the terminal node. It not only improves the channel utilization, but also protects the data communication from the interference of other nodes, realizing the data transmission reliably and efficiently.

5 Simulation and Discussion

To study the protocol performance, we coded some program to simulate the protocol and have an emulation of the property. The initial parameters are set the default value according to the Table 1.

Table 1. Simulation parameter

parameter	value
Regional area	200 meters radius of the circle
The number of terminal nodes	100
Mode of entry	Random access communication area
The number of communication nodes	5
The number of RSSI bands	10
The amount of communication data	256 byte
The rate of the cow	0.2 meter per second

In this experiment, we regard the number of the conflict as one of the most important indicator of assessment about the network communication. This value describes the risk the terminal node may encounter when they are sending an appointment request packet in the channel reservation window. If some terminal nodes are in the same RSSI frequency band, they will locate in the same booking period of the channel reservation window. As a result, the nodes are easy to make conflicts when sending request packets. In this study, we designed an appointment that request packet length is fixed at 100 bytes. The experimental results shown in Figure 4, with the increase of terminal nodes, the network increased the number of conflicts.

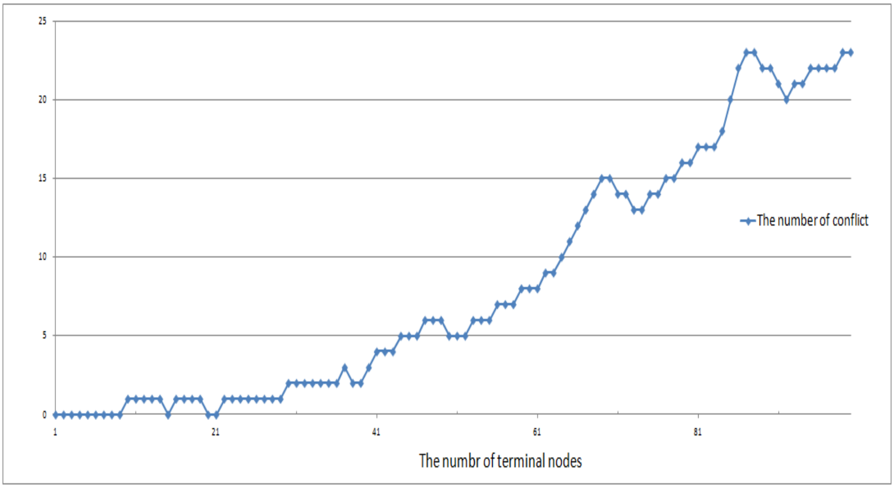

Fig. 4. Relationship between the terminal nodes and the frequency of network conflict

Here the conflict, including all the number of conflicts within the communicated region, some nodes may be encounter more than one conflict. The worst case is when the first appointment is conflicted, and the second appoint after avoidance is conflicted again, the node quits this scheduling cycle. The next scheduling cycle also be continue to meet the conflict. The nodes keep the conflict until they exit the communicated area. It can be seen from Figure 4, the network can't avoid the conflict, and the number of conflict is still at a relatively high frequency range. However, we found when the number of terminal nodes increases to a certain extent, with further increase in the number of terminal nodes, the number of conflicts is rising slowly. Because we use the Backoff algorithm to try to avoid the second conflict, make the total number of conflicts reduction and control it in a certain range. From the curve of the number of conflicts, we can see that after the number of terminal nodes reach a certain number, the increasing of the conflict is less obvious.

In this study, we assume that the number of the channel is 5 and the length of the packet is 256-byte. Under this condition, we study the relationship between the number of starvation and the number of terminal nodes. The simulation results shown in Figure 5, with the increase of the terminal nodes, increasing the number of starvation. The protocol uses the control node to coordinate the communication. However, network conflicts, lack of communication nodes, can also cause the starvation in the booking period. We can increase the number of communication nodes appropriately to reduce the number of starvation.

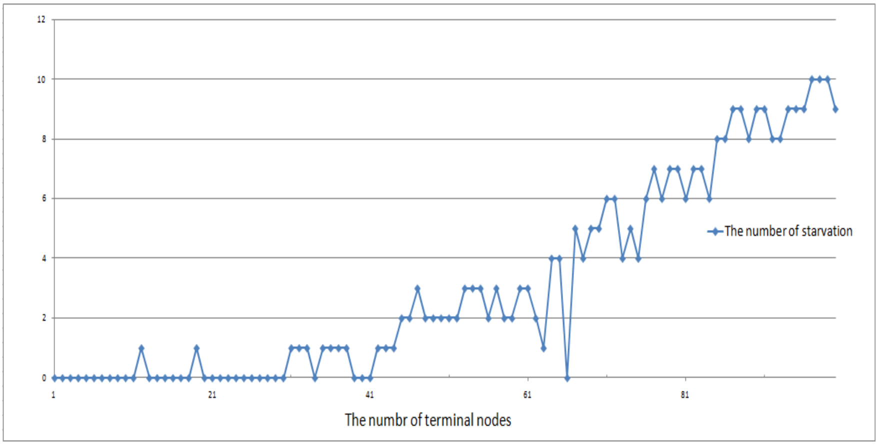

Fig. 5. Relationship between the terminal nodes and the frequency of network starvation

6 Conclusion

In this paper, we presents a multi-channel token assignment protocol in wireless sensor network. The efficiency of energy and stability of transmission is main factor in the design of this protocol. It divides the communication cycle into several windows with special function, and takes RSSI as the channel reservation credential of the terminal node. It reduces the competition of the network access and data collision, extends the dormancy of nodes, saving the energy greatly and extending the life of the network. The protocol uses dynamic channel assignment to improve the utilization of multichannel and the throughput of the network. Simulation results show that it can reach a better energy efficiency and higher throughput. We will study multi-channel token assignment protocol to support the QS and high-level protocol, improving the performance and lifetime of the wireless sensor network further.
hould be treated as a 3rd level heading and should not be assigned a number.

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