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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (11): 2231-2235, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.2231.2235

Research on Funneling-MAC Protocol Based on Broadcast Mechanism

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Abstract: In view of the problem of traditional funneling-MAC protocol, an improved funneling-MAC protocol based on broadcast mechanism is proposed in this study. The listening/sleeping scheduling scheme of broadcast mechanism is introduced to the funneling-MAC protocol. In the proposed funneling-MAC protocol, the nodes are notified in advance when they were the receivers of packets and the node is active only when it is the sender or the receiver and it just got into sleep during other time. So it could avoid on idle listening, overhearing and collision as more as possible. The NS-2 simulation results indicate that the funneling-MAC protocol based on broadcast mechanism is better than the traditional funneling-MAC protocol and it can effectively reduce the system power consumption and maintain higher channel utilization.

Key words: Wireless sensor network, funneling-MAC protocol, broadcast mechanism, listening/sleeping scheduling, NS-2

INTRODUCTION

A Wireless Sensor Network (WSN) (Akyildiz *et al*., 2002) consists of a large number of small, low cost and inexpensive sensor nodes which are equipped with sensing, computing and wireless communicating capabilities. These sensor nodes are randomly located in an area self-organized to be a network. Sensor node is powered by energy limited battery and wireless transceiver module is the largest energy consumption part of the node. Medium Access Control (MAC) protocol controls the wireless transceiver module directly and it plays an important role in the energy consumption of nodes (Kredo and Mohapatra, 2007). Therefore, it is very important and valuable to design an effective MAC protocol to allocate the limited resources of wireless communication.

According to the different practical applications, Many MAC protocols were presented by researchers from different angles (Jian *et al*., 2008). Such as S-MAC (Ye *et al*., 2002), Z-MAC (Rhee *et al*., 2008) and Y-MAC (Kim *et al*., 2008) and so on. Ahn *et al*. (2006) proposed funneling-MAC protocol to solve the problems such as collisions, overhearing and packet loss caused by the large amount of traffic flow data close to the sink in the wireless sensor networks. But the funneling-MAC protocol also has some problems, such as all the data receiving nodes in funneling-MAC protocol are in the listening state during the process of date transmission, with no consideration of collisions, overhearing and idle listening between the nodes, so that it would waste more energy of nodes and reduce the network lifetime (Jian *et al*., 2008). Zhu and Li (2012) proposed an improved funneling-MAC protocol based on DRAND algorithm. Broadcast mechanism is a very important communication mechanism which can effectively avoid data crosstalk and idle listening in the MAC protocol through its listening/sleeping scheduling scheme and it can also reduce power consumption of sensor nodes and increase the network lifetime (Han *et al*., 2011). In this study, the listening/sleeping scheduling scheme of broadcast mechanism is introduced to the funneling-MAC protocol and the protocol is simulated under the NS-2 simulation software to verify its effectiveness.

FUNNELING-MAC BASED ON BROADCAST MECHANISM

Funneling-MAC: The data using in the wireless sensor networks comes from actual monitoring value and the changing network data flow is triggered by an event in the most practical applications. The communication in a multi-hop converge cast sensor network easily leads to data packet collisions, congestion and packet loss as events move closer toward the sink which is called as "funneling effect" (Ahn *et al*., 2006).

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Funneling-MAC protocol is a kind of MAC protocol based on a hybrid TDMA/CSMA approach. This protocol takes the method of CSMA/CA for data transmission network-wide and adopts the hybrid TDMA/CSMA channel access method in the intensity region where is close to the sink node. In the way, nodes close around a sink have more chance to take the method based on scheduling to access channels for transmitting data, so that the problems of collisions and packet loss caused by the large amount of data flow in the region close to sink could be well solved. The funneling-MAC protocol takes CSMA as the main way, sink node periodically broadcasts beacon, only the node which receives a beacon that it can access channel alternately using the hybrid TDMA/CSMA approach, the combination of a TDMA and CSMA frame forms that we call a superframe, as illustrated in Fig. 1. CSMA frame used to transmit date from the node itself and other control information, TDMA frame contains several time slots for scheduling and forwarding the data which is routed from other nodes, sink node gradually increases radio power until the network reaches saturated state. The system clock demand of funneling-MAC protocol is not high and the protocol has higher channel utilization and longer network lifetime.

The goal of designing the MAC protocol for the wireless sensor networks is to meet the requirements of the application and to save nodes energy as more as possible. In the funneling-MAC protocol, all the nodes are in the listening state during the process of data transmission, with no consideration of collisions, overhearing and idle listening between the nodes, so that it would be a waste of more nodes' energy and reduce the network lifetime. The most common approach of reducing power consumption is to alternate sensor node duty cycles between high power active state and low power sleep state. Therefore, in order to solve the problems in the funneling-MAC protocol, the sending and receiving nodes are considered at the same time, the broadcast mechanism listening/sleeping scheduling is introduced into the protocol, the time slots of receiving data are told in advance to the nodes, making sure that only the sending node and receiving node are active and other nodes have gone to sleep in time, so that it can avoid overhearing and idle listening effectively. It also can save nodes energy consumption and extend the network lifetime.

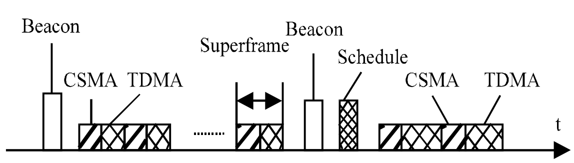

Fig. 1: Division of timeframes in funneling-MAC

Design of funneling-MAC protocol based on broadcast mechanism: Broadcast is a very important communication mechanism. In traditional wired and wireless networks, broadcasting is the host to send the frame to the other hosts in the internet. The broadcast is useful when the host doesn't know the location of the sender and needs to provide data for many machines and it is so important for the application that the host needs to send messages to multiple recipients simultaneously. The realization form of broadcast mechanism in the protocol is the broadcast data frame of the MAC layer (Liu and Ni, 2007). Broad-cast frame is a part of MAC frame header, the node which occupies the time slot sends broadcast data frame and other nodes within two hops receive the frame. If the length of broadcast frame time slot is T_S, the networks access to the phase of data receiving and transmitting after sending a broadcast frame, assume that the length of the data slot is T_D and a TDMA slot is composed of a broadcast frame slot and a number of data slots, so the length of each TDMA time slot is as:

$$TP = T_S + N \times T_D \tag{1}$$

where, N is the number of data transmission time slots.

The period of data transmission protocol of four nodes is shown in Fig. 2. In Fig. 2, transmission round is the length of a transmission period for the nodes, Marked as L_{sync}, the value of L_{sync} depends on the number of nodes in the network, here L_{sync} = 4, each node becomes the owner of time slot once again until waiting for the time of L_{sync} -1. Node's time slot is divided into a broadcast frame time slot and several data slots, the node first enters the broadcast time slot in order to send broadcast frames for broadcasting the transmission scheduling scheme of nodes and then enters several data slots to send data. When the current node's time slot is over, it enters the slot of next node immediately. The scheduling scheme for data transmission of each node is shown in Fig. 3.

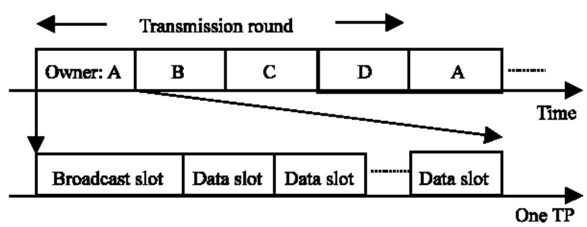

Fig. 2: Period of data transmission protocol

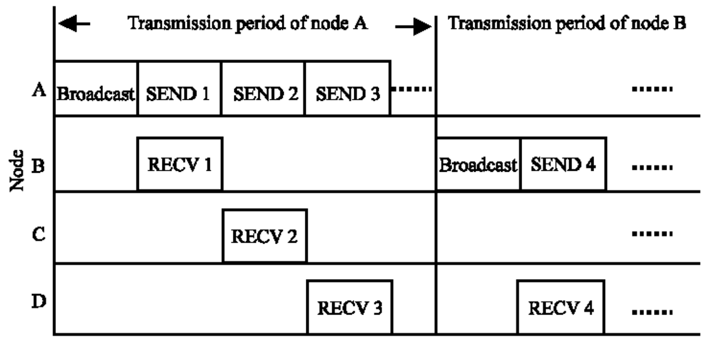

Fig. 3: Scheduling scheme for node data transmission

where, node A is the owner of the current slot and it sends three packets SEND1, SEND2 and SEND3, As shown, node B, C and D are the receiving nodes, because of the node A transmits a broadcast frame in advance before sending data, node B, C and D are active only at the moment of receiving their own data and they are in the state of sleep at other time.

Assume that the four nodes send M packets during a transmission period (Transmission Round), the speed of average data transmission is R, then R is as:

$$R = \frac{M}{TP \times L_{sync}} = \frac{M}{(T_S + N \times T_D) \times L_{sync}} \tag{2}$$

where, the values of T_S and T_D depend on the number of network nodes in practical application of specific, as long as the number of nodes is determined, the values of T_S and T_D are constant while the value of N depends on the setting of parameters in protocol. Therefore, according to the practical application, the design of appropriate value for N has a very important impact on the performance of protocol. After the introduction of broadcast mechanism, the delay of network data trans-mission is as:

$$E(D) = \frac{1}{2}(T_S + N \times T_D) \times (1 + T_D \times R_{app}) L_{sync} + T_S - T_D \tag{3}$$

where, R_{app} is the transmission rate of sensor nodes for specific application and that is the bandwidth. Then we can obtain the average delay of network data transmission AVE(D) as:

$$AVE(D) = AVE(T_{cs} + T_{tx} + T_q) = T_{cs} + T_{tx} + E(D) \tag{4}$$

where, T_{cs} is the average carrier acquisition delay, T_{tx} is the average delivery delay, T_q is the average packet queuing delay.

SIMULATION AND ANALYSIS OF EXPERIMENTAL RESULTS

Since, the funneling-MAC protocol has been proven to be superior to other representative protocols such as B-MAC protocol and Z-MAC protocol (Ahn *et al*., 2006), we only make a comparative analysis between the traditional funneling-MAC protocol and the funneling-MAC protocol based on broadcast mechanism. In order to evaluate the various properties of the protocol, we use the network simulation software NS-2 (http://www.isi.edu/nsnam/ns/) to simulate the funneling-MAC protocol based on broadcast mechanism and the traditional funneling-MAC protocol and the simulation results are compared and analyzed. The initial parameters of simulation are set as the funneling-MAC technical report (http://www.cs.dartmouth.edu/~sensorlab/funneling-mac/TAP-TR-2006-08-003.pdf): the energy of first test node is set into 10J, the deployment scene and the configuration of dataflow use tools of NS-2 to make settings, the application layer uses different intervals of CBR data flow, a zip to remember is that the nodes are static in the simulation experiment and the working frequency of node is 914 $\times 10^6$ Hz of ISM band, the protocol is destination-sequenced distance-vector protocol (DSDV protocol). The simulation of topological structure is shown in Fig. 4. There are 20 ordinary sensor nodes and a sink node, ordinary nodes are randomly deployed, the sending data from node is routed through other nodes and flow to sink node finally. One of the data transmission paths is shown in Fig. 4. As a result of the improved protocol taking the broadcast mechanism, the sending node notices to receiving nodes in advance, only the receiving nodes are in working status and other nodes can be in the dormant state in time. As shown in Fig. 4, node 18 informs the data receiving node 14 in advance through the broadcast mechanism, so the node 15 which is slumbering, does not accept data transmitted from node 18.

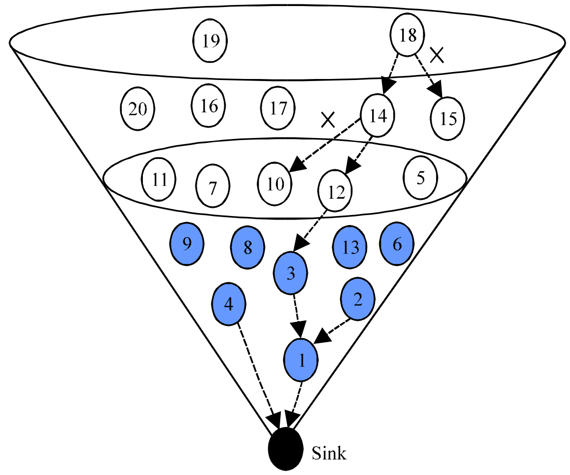

Fig. 4: Topological structure of simulation for funneling-MAC protocol

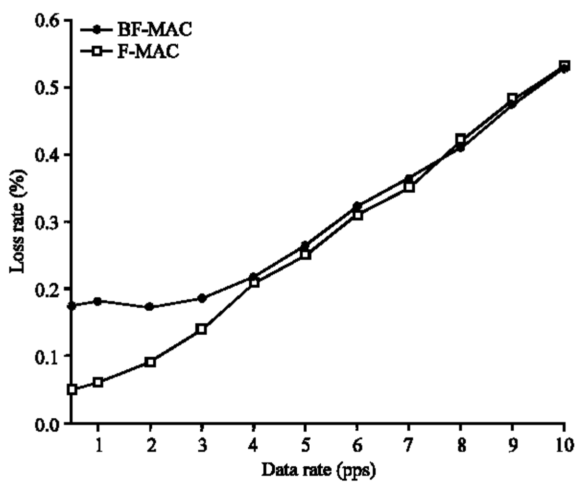

Fig. 5: Performance comparison between BF-MAC and F-MAC on packet loss rate of nodes

The comparison of packet loss rate is shown in Fig. 5, where the "BF-MAC" is the funneling-MAC protocol based on broadcast mechanism and the "F-MAC" is the traditional funneling-MAC protocol, hereinafter the same. In order to save energy consumption in the improved funneling-MAC protocol, the node is in sleep mode in case of no data transmission according to the listening/sleeping scheduling scheme in the broadcast frame. Therefore, the nodes are mostly in sleep state when the data flow is lower in network, if there are data receiving and transmitting, we need to awaken nodes to the operation of data transmission. This process will generate wake-up delay to a certain degree and increases the packet loss rate. As shown in Fig. 5, the packet loss rate of the improved protocol is larger than the

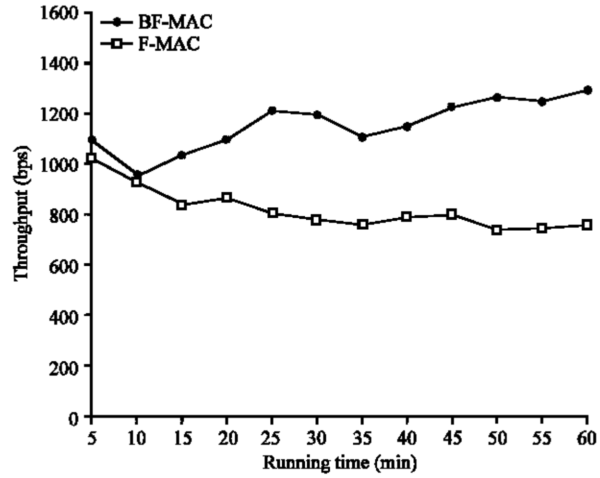

Fig. 6: Performance comparison between BF-MAC and F-MAC on average end-to-end throughput

original funneling-MAC protocol when the data flow is lower in network, but it also can achieve high channel utilization within the extent permitted by the correctness.

The comparison of the simulation between the improved protocol and the original funneling-MAC protocol for the average end-to-end throughput of packet transmission network is shown in Fig. 6 (unit of pps, i.e., how many packets per second to send, the size of each packet is 36 bytes in this study). Since the funneling-MAC protocol based on broadcast mechanism takes the broadcast mechanism, each node in the network only receives its own data and at other times they are in sleep state. As shown in Fig. 6, compared with the original funneling-MAC protocol, the throughput of the funneling-MAC protocol based on broadcast mechanism is increased at the same time.

The comparison of the simulation between the improved protocol and the original funneling-MAC protocol for the average power consumption of network nodes is shown in Fig. 7. The calculation method of average power consumption of network nodes in the study is shown as follows: the total power consumption of all the nodes in the network is divided by the number of nodes. Because the broadcast mechanism is introduced into the improved protocol, each node in the network is notified in advance so that they receive the right data only at the right time and at other times they are in sleep state, so the system can effectively avoid overhearing and idle listening and the system power consumption is saved. As shown in Fig. 7, power consumption of the improved protocol is smaller than the

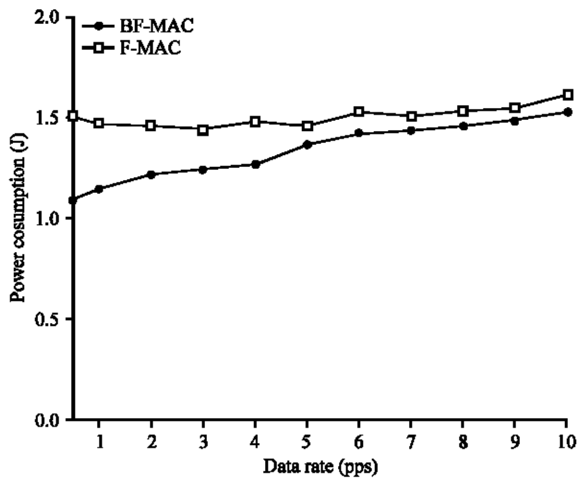

Fig. 7: Performance comparison between BF-MAC and F-MAC on average power consumption of network nodes

original funneling-MAC protocol significantly, especially in the time of low network traffic and nodes are mostly dormant in the state of low data traffic.

CONCLUSION

The funneling-MAC protocol based on broadcast mechanism was presented in the study. The protocol regards saving the power consumption of system as the primary target through the introduction of broadcast mechanism listening/sleeping scheduling scheme. In the proposed funneling-MAC protocol, each node in the network is notified in advance to receive the correct data only at the right time. It can effectively avoid overhearing and idle listening, so that data can be quickly and efficiently transmitted. Simulation results show that the improved protocol can obviously reduce the network power consumption and it can also prolong the network lifetime on the premise of maintaining high system throughput and channel utilization under the same condition. In the future research, we will do more theoretical analysis and verification for the proposed protocol and design more complex simulation and experimental models and also do with more study on the application of the funneling-MAC protocol in the large-scale wireless sensor networks.

ACKNOWLEDGMENT

This study was supported by the Key Project of Guangxi Educational Science Foundation (No. 201202ZD051) and the Doctoral Research Initial Fund of Guilin University of Technology.

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