Traffic aware priority based medium access control protocol for WSN

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ABSTRACT

Considering priority of packets at the sensor nodes while duty cycle calculation is significantly important to reduce energy consumption, end to end delay and unnecessary network contentions of Wireless Sensor Network (WSN). In most of the existing methods in WSN, the duty cycle calculation can be done by low duty cycle operation, gradually increasing duty cycle without considering any parameters and increasing duty cycle by considering higher loads. However, these methods incur large energy consumptions, transmission delays, network contention and are not dynamic to the changes in the traffic load. This paper proposes a priority based traffic aware clustering MAC protocol for wireless sensor network (PCBA-MAC), in which the cluster head node collects the traffic load information from cluster member nodes and calculates duty cycle according to current traffic load based on priority of the packets. Furthermore, an extended sleep cycle for low priority packet nodes are also proposed for energy saving. Simulation results show that the energy consumption and latency is reduced well.

KEY WORDS: Wireless sensor networks, PCBA-MAC, Clustering, Priority, Energy, Latency, Delivery ratio.

1. INTRODUCTION

Wireless sensor Networks (WSNs) consists of a large number of wireless sensor nodes that have sensing, data processing and communication functionalities. WSNs are typically used to monitor a field of interest to detect movement, temperature changes, precipitation etc. The nodes are typically equips with power-constrained batteries, which are often difficult, expensive and even impossible to be replaced once the nodes are deployed. Energy efficiency and time efficiency are two major considerations for sensor data collection in wireless sensor networks. Energy concerns the amount of energy spent in data collection. Since sensor nodes are normally powered by batteries, it is critical to conserve energy as much as possible to extend the lifetime of a sensor network. Time efficiency, on the other hand, refers to the latency of collecting data from sensors nodes to a base station (or a sink node). Sensor data are often required to be quickly gathered information and transfer successfully to the destination.

Duty-cycle MAC protocols have been proposed in WSNs mainly to reduce energy consumption of sensor nodes and latency, since each sensor node operates with their limited energy. One common approach for energy conservation in WSNs is duty-cycling, in which each node switches between active and sleep states, and the active/sleep schedule can vary from node to node. Duty-cycling is easily implementable and is proven to be an effective way for energy conservation. As a result, duty- cycled wireless sensor networks have been adopted by various applications.

Duty cycle calculation in cluster based wireless sensor network is an effective way of cycle calculation. Such a protocol used for cluster based cycle calculation was CBA-MAC protocol. In CBA-MAC, sensor nodes are divided into cluster head node and cluster member node. Cluster head node collects traffic information from cluster member nodes and calculates appropriate duty cycle according to current traffic as the longer awake time is allocated for nodes having higher traffic and longer sleep time for nodes having lower traffic. Then cluster head broadcasts those duty cycle information to cluster member nodes, so sensor nodes can fit for variable traffic occasions well. However, this method incurs contention in network while there is more than one node having the same higher load.

To overcome such problem, this paper presents three class priority based adaptive MAC (PCBA-MAC) protocol over WSN. In PCBA-MAC, sensor nodes are made as clusters, which consist of Cluster head node (CHN) and cluster member node (CMN). There are one CHN and several CMNs in a cluster. CMN contends to active on channel for the transmission of data, and report traffic and routing details to CHN. CHN calculate active cycle based on the traffic, allocating longer and shorter duty time for the cluster member nodes with higher load and lower load respectively. When more than one node has the same higher load compared with other nodes then CHN will calculates the duty cycle based on priority as higher priority packet node will be pre-empted to the lower packet node and broadcasts it to all the CMNs in cluster, which make CMN fit for variable traffic conditions. A proper extended sleep cycle for low priority packet nodes are also proposed for energy saving consideration, so energy consumption can be reduced. PCBA-MAC can get high performance in energy efficiency and also in reduction of latency.

2. RELATED WORKS

BY Liu Hao in 2011, proposes CBAMAC calculates the duty cycle for nodes based on the load of nodes. In CBA-MAC, sensor nodes are divided into cluster head node and cluster member node. Cluster head node collects traffic information from member nodes and calculates appropriate duty cycle according to current traffic and longer awake time is given to node which has higher load and shorter wake time for the nodes having lesser nodes, but it introduces contention when there is more than one node which has same load.

The transport layer protocol enabled priority for wireless sensor networks. Atif Sharif in 2010, proposes the priority concept over storage motes, to achieve prioritization in transmission based on the priority levels (i.e) Source sends the data packets to intermediate storage mote, that storage mote stores packets according to the priority. Then this mote transfer packet to next mote or to sink through priority basis. If there are multiple packets with same priority then the decision will be made on the individual packet TTL value

Lee in 2007, introduces Adaptive-MAC, an adaptive active cycle mechanism, which let length of cycle increases in an exponential style according to traffic for consumption of energy and delay reduction requirements. However, the length of active cycle cannot freely change based on the traffic and hence energy conservation and latency reduction is limited. Furthermore, maintain synchronization between nodes leads to energy waste and time cost.

A priority based packet scheduling method in wireless sensor networks has been proposed by Xianglan Yin in 2006, in which the packets are stored in queue based on priority and when the queue overflows, the lower priority packets are dropped. In this paper the priority was considered for arranging packets in a queue but duty cycle is not calculated based on variable traffic load and priority of the packet.

In wireless sensor networks, the major sources of energy consumption are due to idle listening, control packet overhead, collision and overhearing. To reduce the consumption of energy when ideally listening, active cycle operation is induced in S-MAC by Ye in 2002. Each sensor node in S-MAC follows a periodical synchronized listen-sleep schedule and operates at low duty cycle to conserve energy. Through this method, all nodes were given with same low duty cycle. So this was not more efficient in calculating duty cycle in WSN.

In 2003, T.V. Dam come up with his work, were TDMA based MAC protocols over wireless sensor networks which are naturally energy preserving MAC protocol since sensor nodes can be scheduled for transmission at no collision time slot and go to sleep safely at the rest time. However, maintaining exact schedule in WSN is a complex task and needs a lot of hardware resources. Furthermore, TDMA based MAC protocols need tight synchronization and schedule, which cannot handle topology changes well. Because of these difficulties, this protocol is not suitable for variable traffic load.

System Design: In this priority based cluster MAC protocol (PCBA-MAC), sensor nodes are grouped into clusters. Fig.1, shows the clustering topology in PCBA-MAC. All the CMNs locate in the communication range of CHN, for communicating with the CHN directly. The CHN of neighbor clusters can communicate each other enabling data and control information exchanged between clusters. Furthermore, the transmission power of CHN can be adjusted to get different transmission range. As soon the CHN is selected, it increases its transmission power until the adjacent CHN can communication with it correctly. Then CHN records the communication radius which determines the cluster size. The functions of CHN and CMN are as follows: Cluster Head Node maintain synchronization between sensor nodes in cluster; collect traffic information and routing information from CMNs; calculate duty cycle according to traffic based on three class priority in control of communication between clusters, etc. Cluster Member.

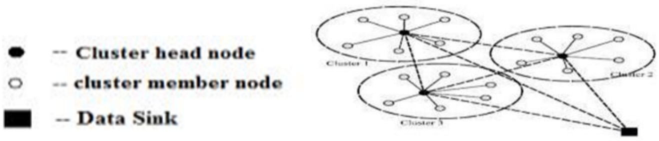

Fig.1. clustering topology in PCBAMAC 1 Cycle Evaluation in PCBA-MAC

The cycle of PCBA-MAC is separated into four phases: SYNC phase, data phase, sleep phase and report phase. Fig.2, by Liu Hao, shows the cycle evolution of PCBA-MAC. Node MN1, MN2, MN3 and MN4 are CMNs and CH is cluster head node. CH broadcasts sync packet in sync phase, so each CMN can receive sync packet and set its duty cycle and updates its local time according to the information contained in sync packet. At the remaining time of this cycle, sensor nodes who do not take part in communication can go to sleep until next sync phase, thus a great deal of energy is saved. Node MN3 and MN4 are the sensor nodes who do not take part in communications, so they can go to sleep at the end of sync phase. Node MN1 is the node having priority packet and MN2 is the node having priority packets.

So in data phase, node MN1 pre-empts the MN2, then the sleep cycle of MN2 was extended for energy saving. MN1 sends the data in data phase. MN2 was in sleep mode. Once MN1 finished sending data, then MN2 starts.

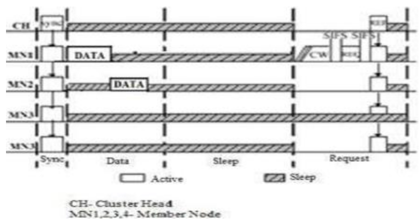

Fig.2. Cycle Evaluation

After completed data transmission MN2 also go to sleep to save energy. After the sleep phase is the request phase, which is divided into many time slots.

Each CMN chooses a random slot to send REQ (Request to reserve) packet to CH, which includes its own traffic information and routing information. If it is the winner of the channel, CH replies a REP (reply) message to confirm the REQ packet. As discussed before, node MN1, MN2, MN3, MN4 can hear REP packet from CH, so after receiving the REQ, sensor nodes know that one node is the winner then the remaining nodes can go to sleep at the rest time of current cycle. If a CMN fails to access the channel in the request phase, it will try to retransmit the REQ packet again until it gets the maximal retransmit limits.

There are three types of packets exchanged in PCBA-MAC other than the data packet: Sync packet (SYNC), Request packet (REQ) and Reply packet (REP). The format of theses packets are shown in Fig.3. The size of these control packets (SYNC, REQ, REP) is fixed and they have different size, but the size is generally small so that energy consumption on transmitting these packets is also not obvious.

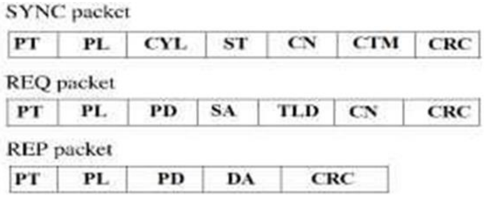

Fig.3. Packet structure

PT= Packet type, ST= Time to Sleep, PD= Packet Duration, CN= Communication Nodes, PL= Packet Length, TLD= Traffic Load, SA= Source address, CRC= Cycle Redundancy check, CLY= Cycle Length, CTM= Current time of CHN, DA= Destination address.

About SYNC Packet

CYL → field with the information of a whole cycle length

ST → information about sleep time of sensor node that how long it go to sleep

CTM → cluster head nodes current time, and all the member nodes of the cluster adjust their time based on the local time.

CN → has routing information of nodes which will take part in communications, so the irrelevant nodes can go to sleep until the request phase to save energy.

About REQ packet

TLD → has the traffic information

All the member nodes in the range of cluster set their active cycle according to the sync phase information. The member nodes can go to sleep until the SYNC if it has no data to send in next cycle. REQ packet also contains the CN field, same as in SYNC packet.

REP packet includes

DA→ about the address of the duty cycle winner.

Priority Levels: Three levels of priorities are considered for the packets in this research work. They are higher priority, intermediate priority and lower priority. For higher priority exponential Flow (video file), for intermediate priority UDP flow (basic CBR file) and for lower priority TCP flow (basic word files) are considered for simulation Nodes having higher priority packets pre-empts nodes having intermediate priority and lower priority packets nodes having by extending the sleep period of the intermediate and lower priority packets. Similarly the nodes having intermediate packets pre-empts the nodes having lower priority packets by extending the sleep period of the nodes having lower priority packets.

Algorithm:

Step1-Startprocess

Step2-CMNs sends REQ packets consisting of traffic information to CHN

Step3-CHN checks the REQ packets and based on traffic load, it calculates the duty cycle by allocating more active period for nodes having higher load.

Step4-If there are more than one node having same traffic load then CHN makes the higher priority packet nodes to pre-empt the nodes having lower priority packets by extending the sleep cycle of nodes with lower priority packets.

Step5- CHN distributes SYNC packets to CMNS

Step6-CMNs adopt to the duty cycle

Step7-Repeat step 2 to step 6 for next cycle

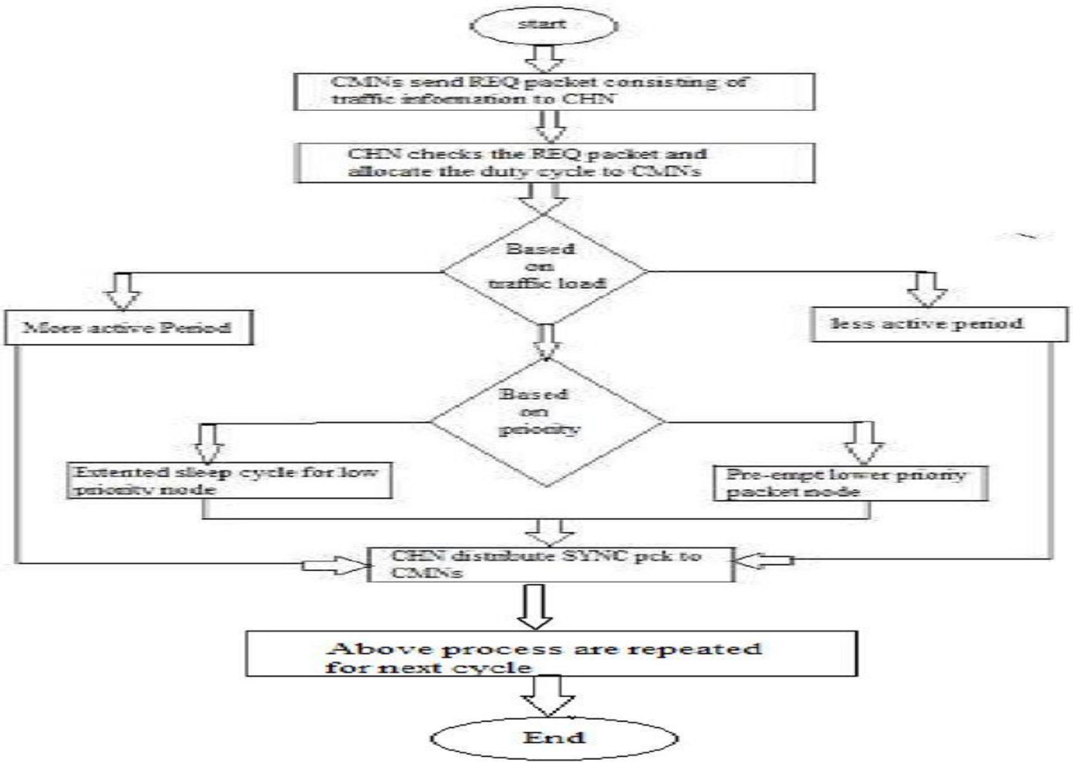

Figure.4. Flowchart

Evaluation of Performance: In this section, we evaluate the performance of the proposed Priority based cluster (PCBA-MAC) protocol through ns-2 simulator. The table.1, shows the simulation parameters.

Table.1. Simulation parameters

No.of nodes	100
Packet Size	512kbytes
Energy at initial	14.10 joule
Power sending	0.66 watt
Power receiving	0.40watt
Power in idle	0.04 watt
Sleep power	0.000003 watt

Based on Rate: Performance of PCBA-MAC and CBA-MAC is analyzed by for various traffic rates by keeping the traffic flow as constant for the parameters energy consumption, delay, overhead, packet delivery ratio and packet drops were calculated based on the constant flow and variable rate. Under this constant flow, three classes of priorities are considered.

Fig.5. Delay Vs Rate

For higher priority exponential Flow (video file), for intermediate priority UDP flow(basic CBR file) and for lower priority TCP flow(basic word files) are considered for simulation. Based on those priority packets, the duty cycle of nodes were calculated by CHN. The node having higher priority packets pre-empts nodes having intermediate priority packets and nodes with lower priority packets by extending the sleep period of the nodes with intermediate and lower priority packets. Similarly the nodes with intermediate priority packets pre-empts the nodes with lower priority packets pre-empts the nodes with lower packets by extending the sleep period of the nodes with lower priority packets.

Delay is the average end to end delay of a packet, which is the duration of the packet sent from the application layer of source to the application layer of destination.

Fig.5, shows the performance comparison between PCBAMAC and CBA-MAC, where the traffic flow is constant and the rate varied.

CBAMAC faces severe contention and delay in presence of mixed traffic whereas PCBMAC avoids them as it calculates the duty cycle according to the traffic information based on priority, but CBAMAC incurs the contention in network when there was more than one node has higher traffic load when compared with other nodes. Because of that contention in network, the nodes have to wait in network for some time to wins the channel. But in PCBAMAC, for that same situation it takes the concept of priority and calculates duty cycle of nodes based on priority as mentioned in section III. Delay of PABA-MAC is 18 % less than CBA-MAC.

So, PCBAMAC has better delay when compared with CBAMAC. From the above result it shows that the PCBAMAC was better than CBAMAC.

Rate vs Energy: Fig.6, shows for the given flow, PCBAMAC has reduced energy consumption than CBAMAC, because in PCBAMAC there are less number of retransmissions and also sleep time is extended for the nodes with lower priority packets but in CBAMAC number of retransmissions are high when compared with PCBAMAC due to contention and the nodes have to wait idle for some time to win the channel and retransmit the packets again.

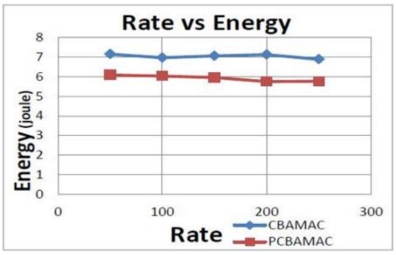

Figure.6. Energy Vs Rate

From the above result it is shown that the PCBA-MAC consumes 13% less energy than CBAMAC.

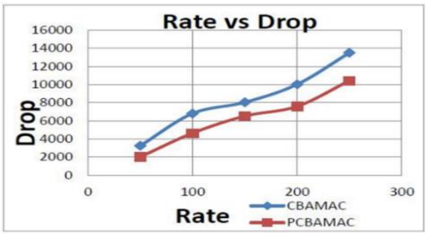

Figure.7. Packet drop Vs Rate

Fig.7, shows for the given rate, the drop was high in CBAMAC when compared with PCBAMAC, because of the excess delay.

The simulation result shows that the PCBAMAC has 13% lesser packet drop than CBAMAC.

Rate Vs overhead: Fig.8, shows for the given rate, PCBA-MAC has lesser overhead as the priority of packets was considered while preparing the duty cycle. The PCBA-MAC has lesser packet drop by considering the priority of packets, hence the number of retransmissions is also very low. Because of high packet drop in CBA-MAC than PCBA-MAC, PCBA-MAC has lesser overhead than CBA-MAC.

Simulation result shows that the PCBA-MAC has 6% lesser overhead than CBA-MAC.

Fig 8. Overhead Vs Rate

Rate vs Delivery ratio: Fig.9, shows for the given rate 100, 150, 200, 250 and 300, PCBA-MAC has the higher packet delivery ratio than CBA-MAC, because the packet drop in PCBAMAC is less when compared with CBAMAC.

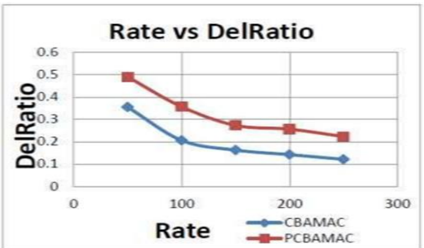

Fig.9. DelRatio Vs Rate

The above simulation result shows that the PCBAMAC has 20% more packet delivery ratio than CBAMAC.

4. CONCLUSION

In this paper, we proposed a priority-based cluster MAC protocol (PCBA-MAC) for wireless sensor network, which dynamically adjusts the duty cycle according to the traffic load and fits for clustering based wireless sensor networks. For simulation, Ns-2 is used and it is evident that the PCBA-MAC has the better performance than CBA-MAC through the simulation results. It provides 18% lesser delay, 13% lesser energy consumption, 6% lesser overhead, 13% lesser packet drop, 20% more packet delivery ratio and on the whole 16.8% better performance compared to CBA-MAC as the preparation of duty cycle is based on the traffic load information and priority of the packets of cluster member nodes by providing an extended sleep cycle for the nodes having lower priority packets.

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