Energy Efficient Congestion Control Hybrid MAC Protocol For Wireless Sensor Networks

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Abstract—Wireless Sensor Networks (WSNs) consist of many sensor nodes, which can be used to monitor physical and environmental conditions. A major challenge in real time implementation of WSN is energy efficiency. Congestion in wireless sensor networks is the major cause for increased energy consumption. Therefore, it is essential to reduce congestion to a greater extent. In this paper, fair share queue model is proposed to control congestion along with Hybrid MAC protocol. The proposed MAC protocol encapsulates hybrid CSMA/ TDMA along with fair share queue model in order to meet delay and throughput requirements. Simulation is accomplished in NS-2 and results show that the proposed approach can control the congestion and increase the energy efficiency, throughput and network lifetime.

Keywords—Congestion control, Fair share queue model, MAC protocol, NS-2, Wireless sensor network.

I. INTRODUCTION

Wireless Sensor network [1] encompass of several puny, low ran, and randomly distributed sensor nodes. It has a skill of detecting, processing and communication above a wireless channel and to tolerate in harsh nature such as Faulty/ dead sensor node, excessive sound etc. Sensor webs have enticed momentous attention as vital groundwork for data collection in pervasive computing environments. In this earth, wireless sensor webs frolic a distinct act in residence automation, environmental monitoring, military, health, and supplementary requests. In WSN, disparate kinds of data are generated and dispatch to the Centre station by nodes. These nodes could be stationary or moving. They can be cognizant of their locale or not. WSN can be categorized into two groups established on data collection and transmission. In event established arrangement, sensor nodes sends the packet to the centre station after the event occurs, while data packets are reported to center station periodically in data flow established ones. After colossal number of sensor nodes is alert simultaneously in sending the data, data traffic increases than obtainable capacity of web. This leads to congestion in network. The main origins of congestion contain buffer overflow, interference, channel contention. Countless to one nature, congestion reasons packet drops at buffer increases queuing stay and increases packet retransmission. This consumes supplementary power and additionally wastage of contact resources. Congestion undeviatingly encounters on power efficiency, cuts link utilization and lifetime of web, lowers the throughput.

There are two kinds of congestion in wireless sensor web.

i) Node level congestion is transpired at particular node after the packet inter entrance rate is larger than the arranging rate ,this consequence in packet defeat , rising queuing stay and needs retransmission of packets .

ii) Link level congestion is transpired due to channel contention, interference, and packet encounter due to accessing transmission medium simultaneously by several alert sensor nodes.

Fig 1: Congestion in WSN

In this paper, we propose efficient hybrid MAC protocol along with fair share queuing models in order to achieve higher throughput and packet delivery ratio thereby minimizing delay.

The primary goal of MAC protocol is to prevent collision which results in higher throughput and delivery ratio with reduced delay [2]. Major energy wastage in the MAC
protocol is mostly due to energy consumption during idle state of the sensor node. This can be reduced by carrying out an alternation between sleep mode and active mode. But, this results in increasing the delay in MAC layer. The energy and delay are two important parameters that have to be taken into account for the efficient design of MAC protocols. In order to reduce the problems associated with delay, hybrid CSMA/TDMA concept is incorporated in the proposed protocol.

This research has been formed as follows; section II includes a summary of related works and describes some of the WSNs protocols. This Section is related to the issues encountered during designing different types of congestion and congestion control in WSNs. Problem statement is given in section III and proposed method is given in section IV. Section V gives us an evaluation of simulation results and the conclusion of the research is included in section VI.

II. LITERATURE REVIEW

Different Congestion Domination Methods are utilized for affecting the congestion in the web. Congestion manipulation method manipulation the traffic in web by properly retaining the web resources. We discover a slight of techniques.

Z-MAC[3] is well-known WSN MAC that adopts both CSMA and TDMA mechanism. In Z-MAC, CSMA is utilized as the baseline scheme and TDMA issued as a “hint” to enhance contention resolution. The owner of one TDMA slot gets higher priority to access the medium by possessing shorter contention window. Non-owners can rob the slot after the proprietor do not have packet to dispatch, this provides good channel utilization. ZMAC only falls back to CSMA in the worst case. But as Z-MAC yet uses fixed TDMA design, topology changes and synchronization errors could alter the protocol property.

B-MAC[4] uses CSMA as its main scheme and adopts LPL and preamble knowledge to preserve energy. Every single node has its own design that is composed of waking period and nap period. Receiver examples the channel and receives the packets. To change to the fluctuating traffic burden, B-MAC can change its nap design by employing an application interface. BMAC achieves elevated throughput and low latency, but it suffers from the eavesdropping setback and the extra energy consumption due to long preamble frame.

In order to avoid indiscriminate dropping of data during congestion, a novel congestion protocol named priority based congestion detection and avoidance in wireless sensor networks is proposed [5]. It provides differentiated data delivery during congestion which comprises of packet priority assignment based on data value, dual queue scheduler for scheduling the next packet to forward based on priority and finally a dynamic dual path congestion aware routing protocol is developed. Simulation results shows that the proposed protocol provides better performance than existing protocols in terms of throughput, packet delivery ratio and packet loss.

Hop-by-hop cross layer congestion control scheme (HCCC) built on contention-based MAC protocol is proposed in [6]. According to MAC-layer channel information including buffer occupancy ratio and congestion degree of local node, HCCC dynamically adjusts channel access priority in MAC layer and data transmission rate of the node to tackle the problem of congestion. HCCC detects local congestion at proper moments, and delivers the congestion information to upstream nodes by exploiting the transmission of RTS and CTS frames. Simulation results demonstrate that the HCCC scheme has good performance in terms of packet loss ratio, throughput, source data transmission rate, and energy efficiency.

Adaptive Duty Cycle based Congestion control (ADCC)[7] is a power effectual and handy heaviness congestion control Scheme, requested above an obligation series established MAC protocol for congestion avoidance in wireless sensor networks. It uses both traffic manipulation way by cutting the packet transmission rate of dispatching node and resource manipulation way by rising packet reception rate of the consenting node. This can be completely established on congestion degree. If the congestion degree is below a precise threshold, the obligation series is adjusted to cut congestion. On the supplementary hand if the congestion degree is above threshold, youngster nodes are notified to adjust the transmission rates.

Congestion detection and avoidance (CODA) [8] proposes an open-loop, hop-by-hop backpressure mechanism and a closed-loop, multi-source regulation mechanism in event-driven WSNs. Sensor nodes notice congestion by monitoring the channel utilization and buffer-occupancy level. In reply to congestion, the congested sensor nodes dispatch backpressure memos to their acquaintances that could drop packets, cut their dispatching rate and more propagate backpressure messages. If the dispatching rate of a basis node is larger than the predetermined threshold, the basis node has to accord a constant stream of ACKs from the base station in order to uphold that rate. By this way, the center station could check the dispatching rate of a basis node established on selecting how countless ACKs to broadcast. CODA employs the AIMD (Additive Rise Multiplicative Decrease) crude rate adjustment. It merely guarantees easy fairness of the congestion control.
III. PROPOSED SCHEME

A. QUEUING MODEL ANALYSIS

Queuing is one of the extremely vital mechanisms in traffic association system. Every single router in the web have to apply a little queuing control that allows how packets are buffered as staying to be transmitted. Every single queuing mechanism has three main constituents that delineate it [9].

- Classification (selecting the class)
- Insertion strategy (determining whether a packet can be enquired)
- Service strategy (scheduling packets to be locale into the hardware queue)

The following queuing models are analyzed for performance:

1. First-in-First-Out (FIFO)

The simplest method to design a packet in each web is FIFO. Here the early packet in the queue is assisted early in a particular period slot, even though of each prioritization, protection or even fairness. Hence it is extremely easy to implement. Though, it fails to accomplish all supplementary arranging properties except complexity, FIFO suffers from head of the line (HOL) subject, in way that if the early packet in the queue is blocked for each reason, the rest is blocked even nevertheless the link is inactive.

2. Priority Queuing (PQ)

Priority Queuing [10] is industrialized to vanquish the setback of the FIFO that does not furnish each prior to each classes or each data traffic. PQ usually ensures the fastest ability of elevated priority data at every single point whereas it is utilized. It gives severe priority to the traffic that is extremely important. The arrangement of every single packet in one of four queues described as-high, medium, normal, or low is gave established on the allocated priority of every single packet.

The possible drawback of this arranging mechanism is that, the lower level traffic might not be assisted for a long period, if the elevated priority is always there. As a consequence the lower class will tolerate from a starving setback, which leads to a momentous discard of the packets.

3. Fair share queue

The drawbacks of the FIFO queue and priority queue are overcome in the proposed fair share queue. Fair share Queuing [11] is the foundation of assorted queuing mechanisms that are projected to safeguard that every single flow has fair admission to web resources. Bandwidth is allocated fairly amid all the flows. So packets appeared early (in FIFO) and packets of elevated priority will not monopolize the finished bandwidth. Here the flows that are dispatching extra number of packets or colossal packets in size i.e. the packets of hostile flows are dropped. So the misbehaving flow will not be annihilative to supplementary larger behaved applications. Fair queuing algorithms can accomplish fair bandwidth allocations by maintaining per-flow state and information. If there are n numbers of alert flows next every single flow is allocated 1/n of the output bandwidth. As the number of flows adjustments, the number of bandwidth allocated to every single of the queue additionally changes.

![Fig 2: Fair Share Queue](image)

B. HYBRID CSMA/TDMA MAC PROTOCOL

Hybrid MAC [12-15] protocol merges the merits of TDMA and CSMA as offsetting the demerits of both the schemes. Hybrid-MAC uses CSMA at the center but follows TDMA reliant on the contention level. The overhead of Hybrid-MAC protocol is the setup period that is completed at the beginning. In the setup period, the nodes are allocated alongside the timeslots for the data transmission. The nodes use the allocated timeslots for the transmission of the detected data in a particular era of period recognized as frame. A node is shouted the proprietor of a period slot if it wins the admission of the transmission medium; or else the node is recognized as non-owner.

The non-owners of the period slot have lower priority to send the data after contrasted to that of proprietors of the period slot. The priority is set employing the contention window size. If at a particular point of period, the proprietors do not send the data, next the non-owners of the period slot could send the data by employing the period slot that is left new by the proprietor of the period slot.

![Fig 3: Proposed System Block Diagram](image)
Hybrid-MAC protocol performs better comparable to TDMA after the level of contention is low (or the traffic burden is low) and it performs better comparable to CSMA after the level of contention is elevated (or the traffic burden is high).

C. TRANSMISSION CONTROL OF HYBRID MAC

The function of a node begins after it senses an event and network function begins after a node starts sending the detected event in the form of message, data, frame or packet etc. All the nodes in the network are randomly deployed. A node is licensed to sense for events, allocate the data alongside supplementary nodes, onward the data to a head node or sink node all the period till the battery manipulation drains.

Fig. 4: Flow diagram of the proposed hybrid MAC protocol

As a node acquires frame to send, it checks whether it is the proprietor of the present slot. If it is the proprietor of the slot, it seizes a random period inside a fixed time period. Across this random period the node keeps the frame into prepared state, checks for the rank of one and two hop neighbors, and performs innate synchronization amid neighbors. After the timer expires, it runs Clear Channel Assessment (CCA)[16]. If the channel is clear, it transmits a message to one hop neighbors. The message encompasses data such as kind of data in the frame, frame size, routing data, basis of the frame, path across that the frame is to traverse and the destination ID. On consenting the message a receiver computes the distance from the source, slant of entrance, packet defeat ratio and transmits it alongside with the ACK message. On receiving an acknowledgement message, the source node computes the distance of entrance, and transmits DOA along with the early frame. If the channel is not clear, next it waits till the channel becomes free.

If a node is not a proprietor of the present slot, and is in LCL, or in HCL, and the present slot is not owned by its two-hop neighbors, it waits and back off inside a contention window. After the timer expires, it runs CCA. In case it finds the channel clear, it starts transmission. If the channel is not clear, it waits till the channel becomes clear, and next repeats the above process. Further, if a node is not a proprietor of the present slot, and it receives ECN memo from its two hop neighbors, it checks its acquaintances for a node alongside LCL, as a node alongside HCL can always avail the present slot of LCL node to present higher priority task. The node alongside LCL gives present sending slot to HCL and goes into nap mode and postpones its transmission till it finds a period slot that is not owned by a one hop and two hop neighbors. ECN message is generated by one hop acquaintances of a final destination node.

IV. PERFORMANCE EVALUATION

In this section, we furnish an evaluation of the proposed hybrid MAC protocol alongside the fair share queuing model. The presentation metrics seized into the report are energy efficiency, packet transport ratio and delay. The energy efficiency of the sensor nodes can be described as the finished energy consumed/total bits transmitted. Energy is the scarcest resource of WSN nodes, and it determines the lifetime of WSNs.

1. Energy efficiency

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Fig. 5: Energy efficiency Vs nodes

The performance of various queuing model is plotted in the graph showing the number of nodes against the energy (in J) in the Figure 5. With the increase in number of nodes,
the energy consumed by the nodes also increases. From the graph, it is clear that the energy consumption of FS queue model is less when compared to DRR and PQ.

Fig.6: Energy efficiency Vs packet size

Figure 6 shows the comparison between energy and packets size. When packets size has been increased, the energy consumed by nodes also increased. From the graph, it is clear that the energy consumption of FS queue is less when compared with DRR and PQ.

2. Packet delivery ratio

Packet delivery ratio is the ratio of number of packets received to the number of packets sent averaged over all the nodes. Packet delivery ratio is a measure of how successfully the generated packets reach the sink/base station.

Fig.7: Packet delivery ratio Vs number of nodes

Figure 7 shows the performance of the various queueing model with respect to variation of nodes vs packet delivery ratio(%). When the number of node increases, the packet delivery ratio decreases. From the graph, it can be seen that packet delivery ratio is more for FS queue compared with DRR and PQ.

3. Delay

The average delay is the average time taken by the packets to reach the base station.

Fig.8: Packet delivery ratio Vs packet size

Figure 8 shows the comparison between various queueing model with respect to packet delivery ratio. When packets size has been increased, Packet delivery ratio of node decreased. From the graph, it is clear that the packet delivery ratio of FS queue is more when compared with DRR and PQ.

Fig.9: Delay Vs number of nodes

Figure 9 shows the delay variation between different queueing models when number of nodes increased average time taken by the packets to reach the base station also increased. From the graph, it is clear that the average time taken by the FS queue is less when compared with DRR and PQ.

Fig10: Delay Vs packet size
Figure 10 shows the comparison between various queuing model with respect to Delay and packets size. Delay has been increased by changing the packet size. From the graph, it is clear that the delay of FS queue is less when compared with DRR and PQ.

V. CONCLUSION

In WSN, data flow leads to unpredictable load, it causes congestion due to many-to-one nature of traffic. Congestion may also occur due to limited wireless bandwidth of sensor network. Congestion leads to wastage of the energy of the nodes. To control the congestion in a very high traffic environment, MAC protocol can be designed in an efficient manner.

The performance of various queuing models such as Fair Allocate, DRR and Priority Queue are compared with respect to parameters like energy, packet delivery ratio and delay. Simulation results demonstrate that Fair share queue can perform well with low delay and high energy efficiency in many sensor network applications which can be incorporate with hybrid MAC protocol.

REFERENCES


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